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of the sea urchin, Strongylocentrotus intermedius

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ON THE NATURAL SEEDS COLLECTION, INTERMEDIATE CULTURE, AND RELEASE
OF THE SEA URCHIN, *Strongylocentrotus intermedius*

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Department of Mariculture,
Hokkaido Central Fisheries Experimental Station,
Shiribeshihokubu Fishery Extension Office
and Hokkaido Institute of Mariculture

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The production of sea urchins (weight, unshelled) in Hokkaido amounts to about 1 ton, with a value of 12 billion yen, so that sea urchin fishing is the most important shallow-sea fishing industry after kelp and scallops. The principal species of urchins caught in Hokkaido are *Strongylocentrotus intermedius* and *S. nudus*, with the former accounting for 80% of the catch, and distributed all over Hokkaido, in regions with reefs and stones along the shore.¹ In recent years Hokkaido urchin production volumes have become relatively stable all over the prefecture, but annual variations from one municipality to the next are extremely unstable.²

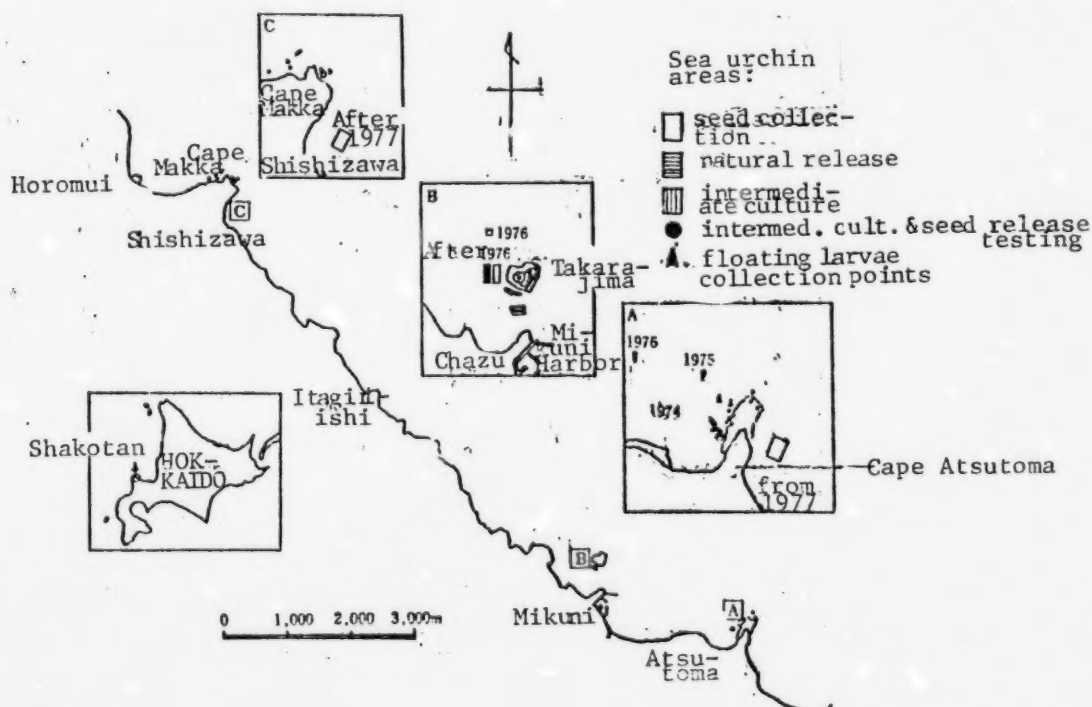
In sea urchin resource propagation in Hokkaido, policies for resources control, transplantation, etc., have been vigorously advanced since the late 1950's and early 1960's, and recently, many efforts have been made in the creation of fishing grounds. In addition, to aim at a great increase in natural resources, a strong requirement for large numbers of seeds has developed.

It happens that young urchins, *S. intermedius*, adhere to and grow on scallop culturing facilities, and in one region of Funka Bay (= Uchiura Bay), such young urchins were collected and used as seeds, and depending on the year, 1 million units might be collected. However, there was great annual variation in numbers, and it was also difficult to supervise urchin seeds in combination with scallop culturing, so that it was thought necessary to establish techniques for stabilizing intensive collection of young urchins alone.

In 1972, KAWAMURA et al. effected small-scale urchin natural seeds collection tests in Ninro Bay, Otaru City, and indicated the possibility of such collection.³ Later, in the 10 years from 1974 to 1983, the Hokkaido Development Bureau, in a Japan Seacoast Maricultural Development Survey, implemented developmental testing on methods of natural seeds collection, intermediate culture, and release of urchins at Mikuni, Shakotan-cho (Fig. 1), and developed basic

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Fig. 1. Location of survey testing areas



techniques. Using these, the Mikuni Fishing Cooperative implemented natural seed collection and secured 1 million seed units. This survey was entrusted by the Hokkaido Development Bureau directly to the Department of Mariculture, Hokkaido Central Fisheries Experimental Station, and the Shiribeshi Hokubu Fishery Extension Office. In addition, the Hokkaido Institute of Mariculture was in charge of part of the laboratory experiments. Results of the surveys extending over 10 years have been published at intervals as reports by the Hokkaido Development Bureau⁴⁻¹⁰; here we present a summary to serve as reference to a large number of readers.

The names of the 28 participants in the survey follow in alphabetical order. The contents of the present report have been assembled and prepared for publication by Hirokazu KAWAMURA.

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*It is often impossible to be sure of the proper reading of a Japanese name. Asterisked are names which are written in characters with multiple readings.
--Translator's note.

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Before proceeding to the main body of this report, the author wishes to express his gratitude for the cooperation over a 10-year period given him by the personnel and membership of the Mikuni-cho Fishing Cooperative, and the personnel of the Shakotan Fisheries Section.

I. Life cycle and environment of *Strongylocentrotus intermedius*, from birth to benthic stage

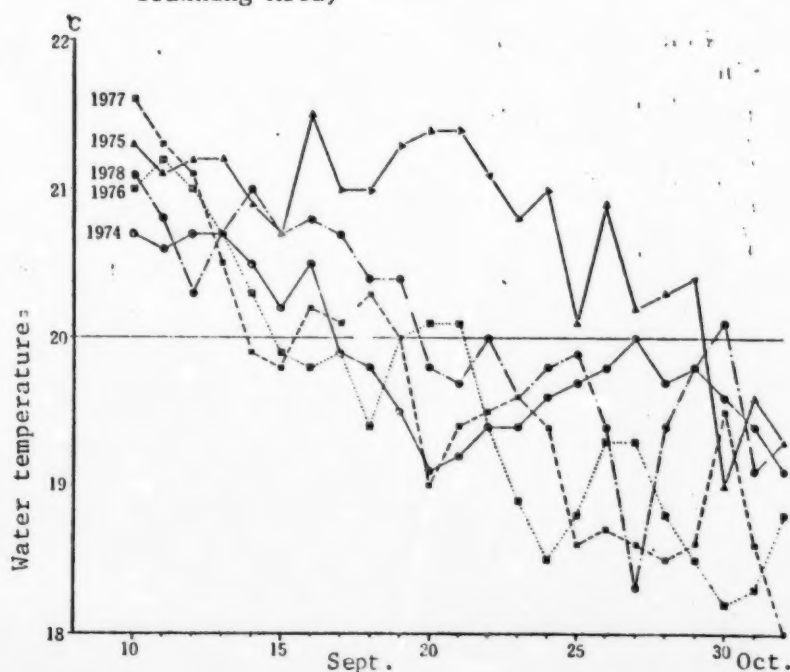
1. Free-swimming larvae

(1) Hatching process

The spawning period of *S. intermedius* off the coast of Shakotan lasts from September to the middle of October, beginning when the water temperature falls below 20°C, and ending when it reaches 15°C. The period when it falls to 20°C varies annually (Fig. 2), so that the spawning stage may vary by about 1-2

Fig. 2. Annual variations in autumn water temperature
(Otaru Fisheries School, Furubira Maricultural Training Area)

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weeks, depending on the year.

The eggs of S. intermedius are fertilized in the sea and sink to the floor. They reach the embryo stage, hatch, and float up; after 2 days they become plutei and able to feed.

The pluteus stage is divided according to the number of arms into periods of 4, 6 and 8 arms. In the 8-arm period, the urchin primordia develop on the ventral half, and spines and tube feet are formed. The process in which the primordia emerge from the ventral portion of the pluteus, the pluteus body is absorbed and the urchin takes form is metamorphosis. The metamorphosed larvae sink and enter the benthic stage. Larvae in the 8-arm period are 1 mm long. The shell diameter of the metamorphosed larvae is about 350-450 μ . The free-swimming period of cultured urchins can be as long as 20 days, but in nature it lasts for 2-3 months. In general, the lower the water temperature, the longer the free-swimming period. The metamorphosed larvae virtually do not collect on substrates without inserted adhering organisms.^{11,12}

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(2) Distribution and locomotion

Table 1 indicates the number of plutei appearing in one catch of a plankton net (mouth radius 30 cm, mesh XX13) vertical tow, in locations at a depth of 9 m (Fig. 1). S. intermedius larvae with 4 arms appear from late September to mid-October, and 6-arm and early stage 8-arm larvae are almost absent, but they appear metamorphosed from the late 8-arm period, from November to January.

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Fig. 3 indicates the number of larvae per catch of a plankton net vertical tow up to 5,000 m offshore, at 500-1,000 m intervals, and a depth up to 30 m. In October, 4-arm period larvae predominate and are numerous along the coast, but in November the 8-arm period larvae are heavily distributed offshore, and in December the metamorphosed young urchins are numerous within 3,000 m of the coast. It is not clear how far from the shore urchin larvae are distributed, but since they appear as well in surveys 10,000 m distant, they undoubtedly

Table 1. Period variations in numbers of free-swimming larvae, by collection at stations (1976, depth 9 m)

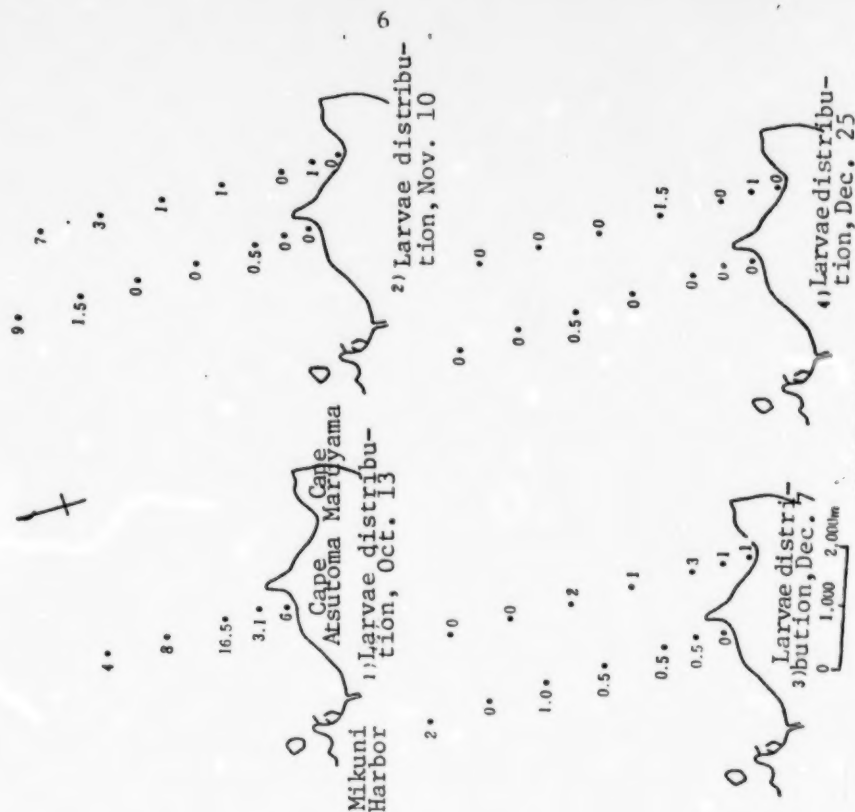
Month		September																											
Species	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Strongylo-	4 " stage																												
centrotus	6 " "																												
inter-	8 " early																												
medius	8 " late																												
	Metamor.																												
S. nudus	4 " stage																												
	6 " "																												
	8 " early																												
	8 " late																												
	Metamor.																												

Month		October												November															
Species	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Strongylo-	4 " stage																												
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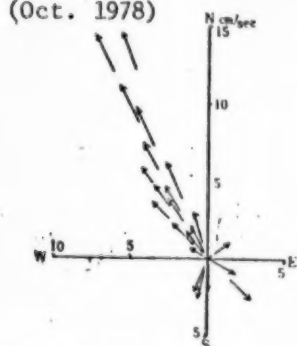
Month		December												January															
Species	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Strongylo-	4 " stage																												
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S. nudus	4 " stage																												
	6 " "																												
	8 " early																												
	8 " late																												
	Metamor.																												

(Per 1 catch, vertical tow)

Fig. 3. Distribution of *S. intermedius* free-swimming larvae (1976)



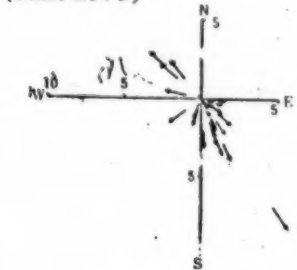
(Oct. 1978)



(Nov. 1978)

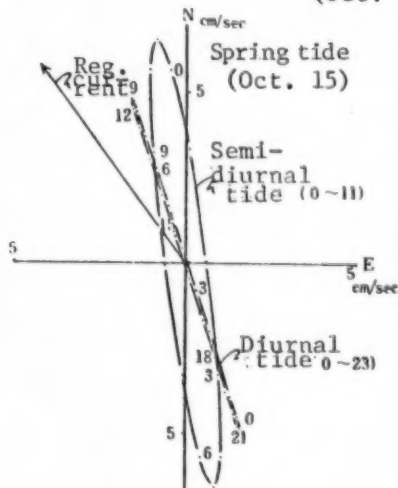


(Jan. 1979)

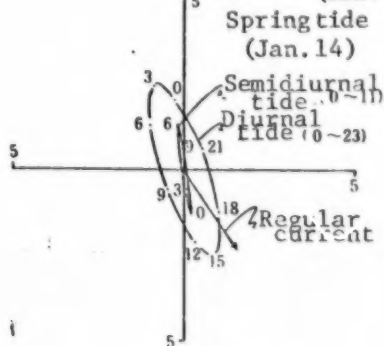


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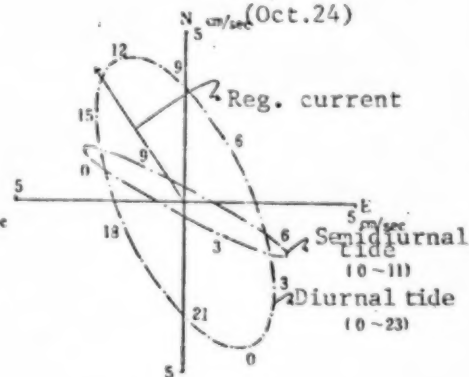
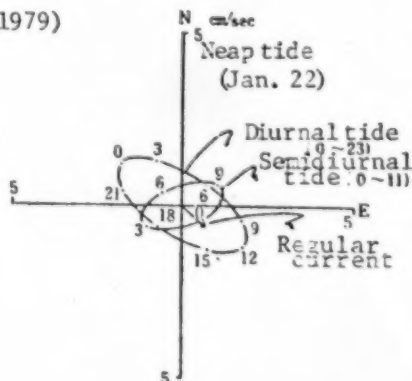
(Oct. 1978)



(Jan. 1979)



Neap tide
(Oct. 24)

^s Neap tide
(Jan. 22)

For both regular and tidal currents, from October to about mid-November, the currents toward the northwest prevail, and their velocity is rather high. From late November to January, currents toward land to the southwest become numerous, and velocity gradually lowers.

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From the above, it may be supposed that free-swimming larvae in the 4-arm period follow ocean currents and gradually disperse and move into the offing, where they spend their 6- and 8-arm periods, and that on commencing metamorphosis, they enter currents moving towards land, and once more accumulate and adhere in shallow-water areas.

(3) Annual variations in natural decrease and numbers appearing

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Table 2 presents figures for the mean numbers appearing of free-swimming larvae per catch from plankton net vertical tows in October, November and December in the 3 years 1974-1976, in the areas surveyed. Rates of natural decrease for larvae from October to December are: 1974 - 95.4%, 1975 - 75.8%, and 1976 - 93.2%, so that decrease in the free-swimming larval stage may be considered high. Numbers of 4-arm period larvae vary annually, as do those of larvae around the time of metamorphosis, and as Fig. 16 shows, the maximum in the last 9 years is 2.75 (1979) and the minimum 0.07 (1975), or a 40-fold variation.

Table 2. Numbers of free-swimming urchin larvae appearing per catch, by plankton net vertical tow

Collection	Yr.	Mo.	Date	<i>Strongylocentrotus intermedius</i>	<i>S. nudus</i>
	1974	10.	8	5.05	21.62
	1975	10.	17	0.92	3.12
	1976	10.	13	13.10	31.00
	1974	11.	6	1.19	0.09
	1975	11.	12	0.11	0.11
	1976	11.	10	1.71	0.25
	1974	12.	10	0.23	0
	1975	12.	12	0.22	0
	1976	12.	7	0.89	0.11

As for numbers of larvae appearing in December, if distribution is considered as up to 5,000 m offshore, variation is between 5 million per Km of coastline (1975) and 20 million (1979), and despite great natural decrease in the free-swimming stage, it may be supposed there is an enormous number of metamorphosed urchins which can settle.

2. Benthic stage

(1) Habitat

The benthic stage of Strongylocentrus intermedius is from settling to 1 whole year. Concentrated distribution often occurs on rocks under 30 cm diameter, or is small vertical communities of seaweed on flat beaches. Moreover, there is almost no change in habitat during this period, and shifting is rare.¹³

Nutrients for the young urchins up to a shell diameter of 5 mm are adhering diatoms and detritus; up to 5-10 mm, other algae are added, and above 10 mm, algae predominate.¹³

(2) Growth

On the Shiribeshi coast, the young urchins that have settled from December to January grow to about 1 mm in February, 2-3 mm in June, and 5-7 mm in September; these rates are slower than for other coastal areas (Table 3).

Table 3. Regional variations in shell diameter of S. intermedius, by age

Region	Age						Method
		1	2	3	4	5	
Funadomari ^m		8.4 _{cm}	25.4 _{mm}	37.4 _{mm}	46.4 _{mm}	53.0 _{mm}	A
Oiso (E.Rishiri) ^m		9.4	31.4	47.7	59.4	67.3	C
Wakkanai ^m		—	39.2	55.7	59.9	67.3	C
Mashike ^m		8.0	32.7	53.7	58.7	61.9	C
Oshiro (depth 2m) ^m		7.7	25.1	37.6	46.4	53.0	A, C
" (" 5-7m) ^m		7.1	25.1	36.3	43.4	47.8	C
Shakotan ^m		7.3	26.3	41.0	49.6	53.3	C
Southern Region ^m		15.7	33.1	42.6	49.2	54.9	A, B
Ikandai ^m		12.5	27.5	39.0	47.5	54.0	A
Rausu ^m		18.1	33.5	44.3	53.2	60.9	A
Abashiri ^m		10.1	24.6	36.6	48.9	51.8	C

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A. Analysis of shell composition
B. Culture
C. Age assessment

(3) Distribution and annual variation

The early benthic stage of the young urchin is extremely short, and it is difficult to make quantitative surveys of amounts distributed. On considering annual variations in mean density (Table 4) on the coast of Cape Atsutoma in May-June when shell diameter has reached 2-3 mm, it is found that annual variation is extremely high, extending from $0.5/\text{m}^2$ in 1982 to 100 times that value, $52.6/\text{m}^2$ in 1980. Numbers of free-swimming larvae in December 1979 are the maximum in the survey period; this also explains the great distribution of benthic urchins in 1980.

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(4) Natural decrease

Density of young urchins on the coast in May-June is almost consistently below $15/\text{m}^2$, but as will be shown, it is usually above $100/\text{m}^2$ on a collecting apparatus. Amounts adhering to the natural seeds collector has no great correlation to distribution on the coast (Fig. 6). This probably indicates that

Table 4. Density of young *S. intermedius* urchins on beaches

Year	Age	Number/ m^2		
		May-June	Sept.-Oct.	Sept.-Oct. density May-June $\times 100$
1975	0	10.0	5.7	57.0
	1	5.0	3.4	68.0
1976	0	2.8	1.4	49.8
	1	4.1	3.2	79.2
1977	0	11.4	4.0	35.0
	1	1.7	1.1	75.4
1978	0	1.3	0.4	28.3
	1	0.8	0.4	45.0
1979	0	12.3	0.5	4.1
	1	1.6	0.3	18.8
1980	0	52.6	—	—
	1	0.9	—	—
1981	0	2.6	—	—
	1	0.3	—	—
1982	0	0.5	—	—
	1	6.0	—	—
1983	0	2.0	—	—
	1	6.4	—	—

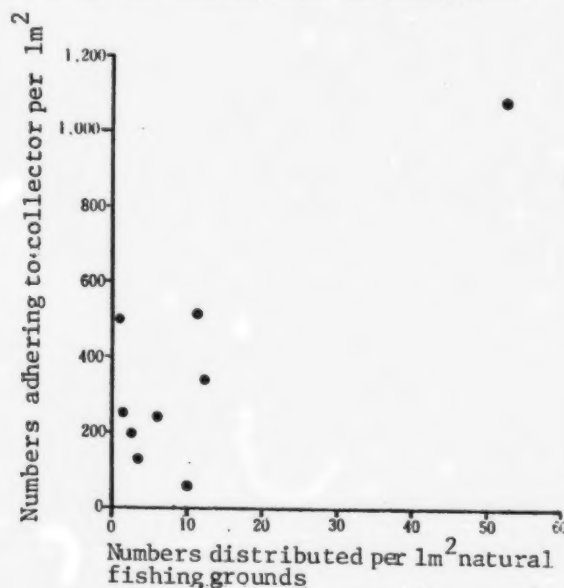
NOTE: The Autumn, 1979 survey took place on November 21.

Fig. 6. Correlation of numbers of young urchins in natural fishing grounds and in seed collectors

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Natural fishing grounds: shallow coastline, depth under 1 m, Cape Atsutoma (May-June).

Seed collectors: Atsutoma, 2 or 3 vinyl chloride corrugated sheets, 30 x 30 cm, superposed (March-April).



settling conditions in natural fishing grounds are unstable.

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There are annual variations in survival rates for young urchins from May-June to September-October, at: maximum 57%, minimum 4.1%; the decrease is extremely sharp (Table 4). The reasons, from observations and test results to present, are large-scale consumption by crabs and starfish, and mass deaths, including large urchins, in years when summer water temperatures exceed 22-23°C and a high-temperature period continues.

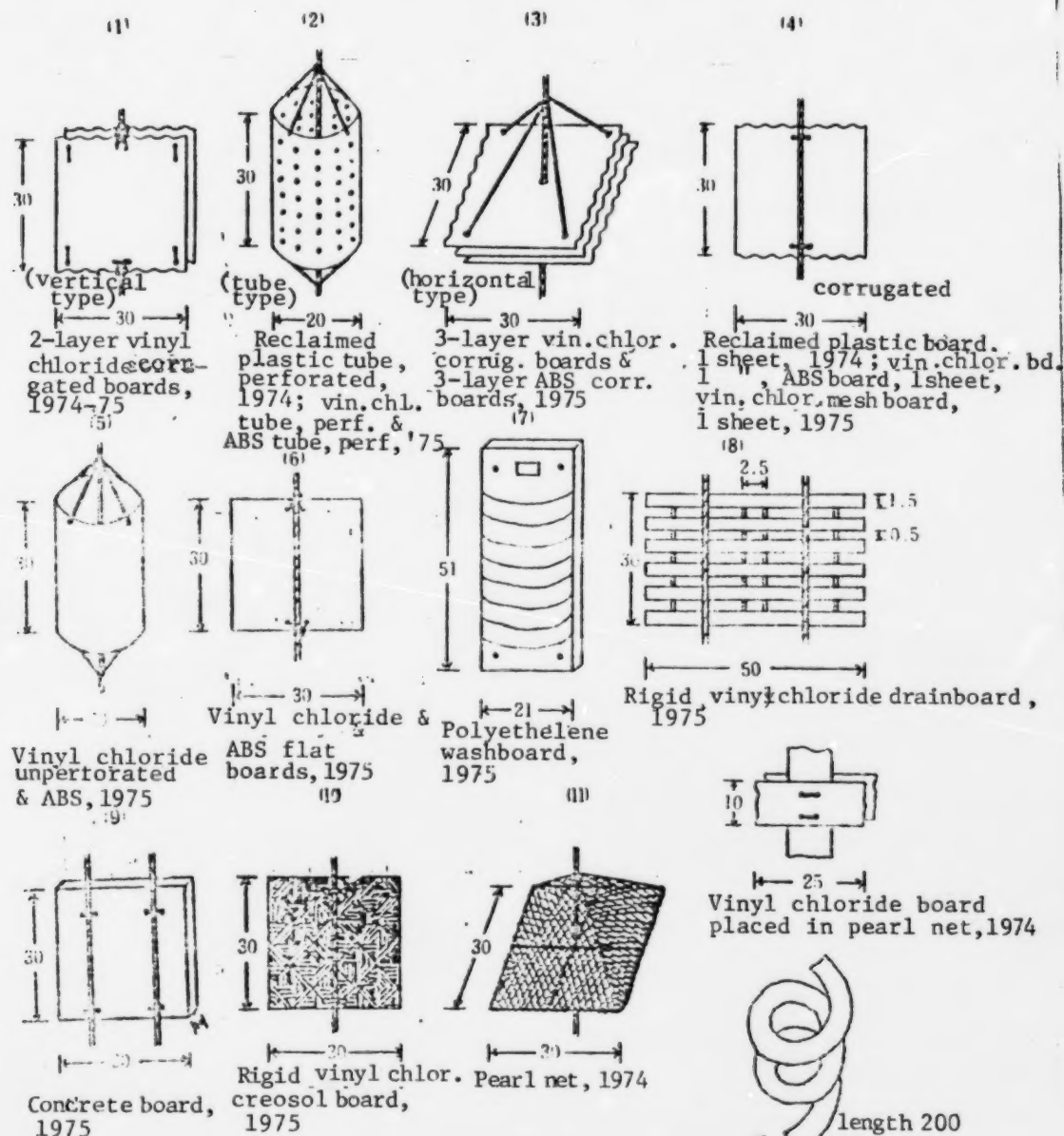
II. Natural seed collection experiments

1. Outline of testing methods

(1) Collectors: materials and construction

Figures 7-10 indicate materials and construction for seed collectors used in the 5 years 1974-1978. Used were vinyl chloride corrugated boards, plastic creosol boards, synthetic resin washboards, and 10 other materials.

Fig. 7. Types and construction of seed collectors, 1974 and 1975
(unit: cm)

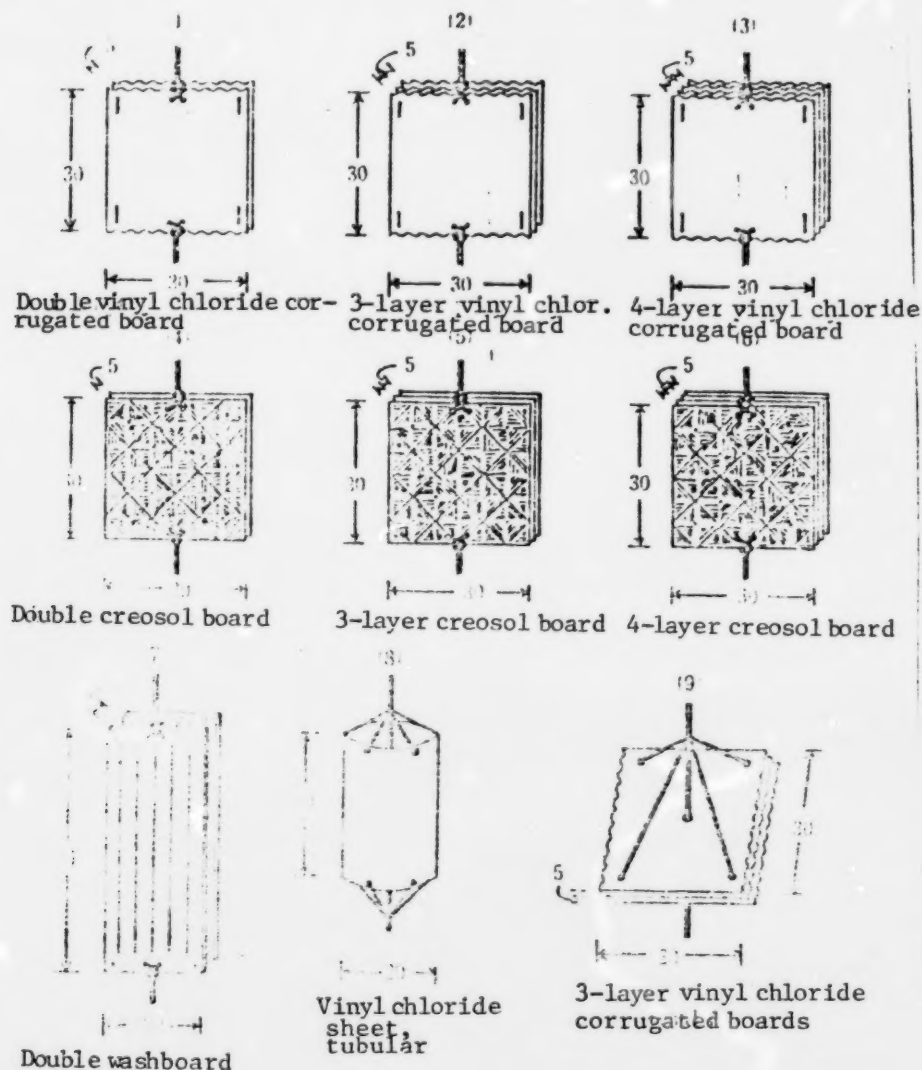


ABS: Acrylic nitrile, butadiene, styrene composite board (commercial name)

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Fig. 8. Types and construction of seed collectors, 1976 (unit: cm)

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For construction, various types were tested, vertical, horizontal and tubular; the method of insertion in pearl nets was attempted, and various techniques such as superposing layers and changing sizes.

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(2) Suspension facilities for collectors

① Fixed suspension method (Fig. 11)

Type I: 9 suspended collection lines 30 m long, 3 m apart.

Type II: 14 suspended collection lines 50 m long, 3 m apart.

Type III: 18 suspended collection lines 50 m long, 2.4 m apart.

Fig. 9. Types and construction of seed collectors, 1977 (unit: cm)

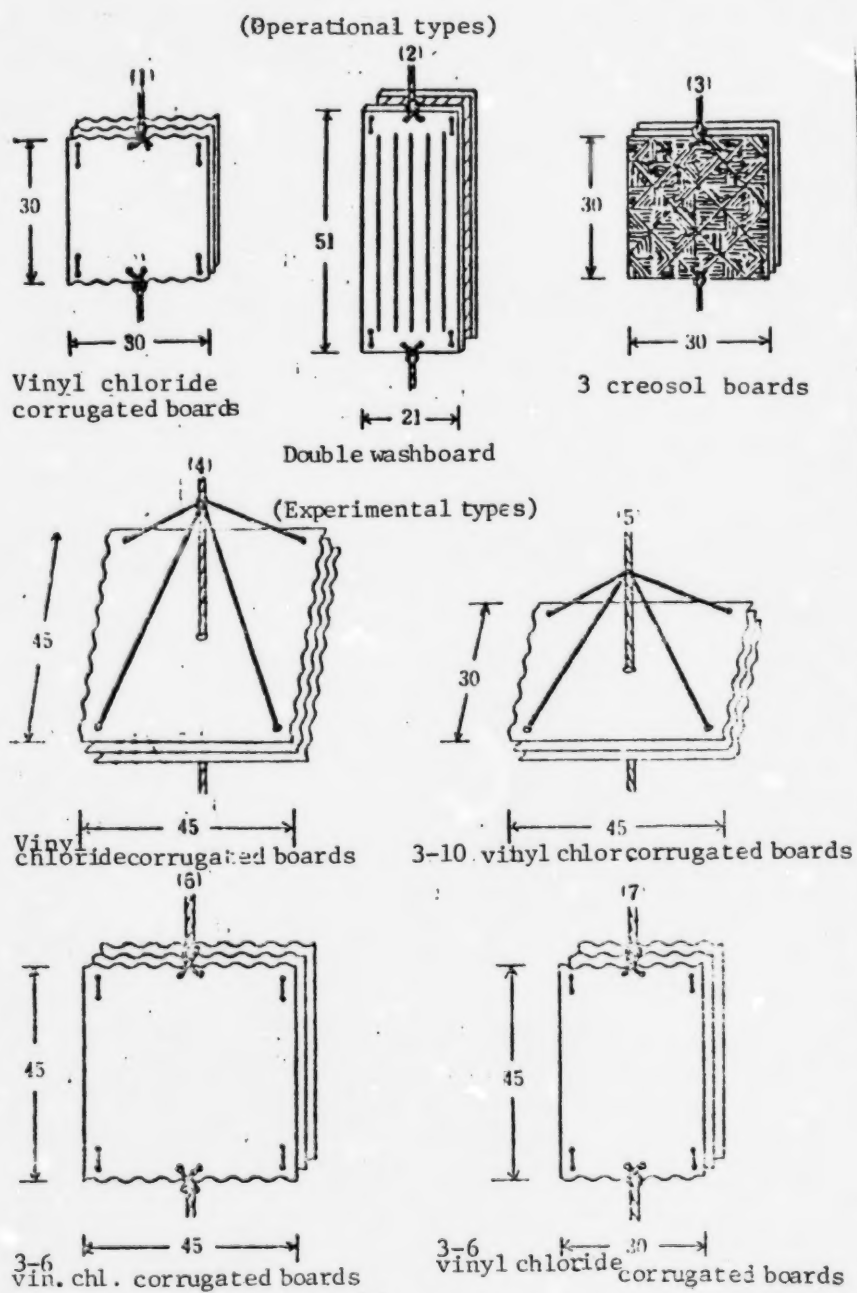
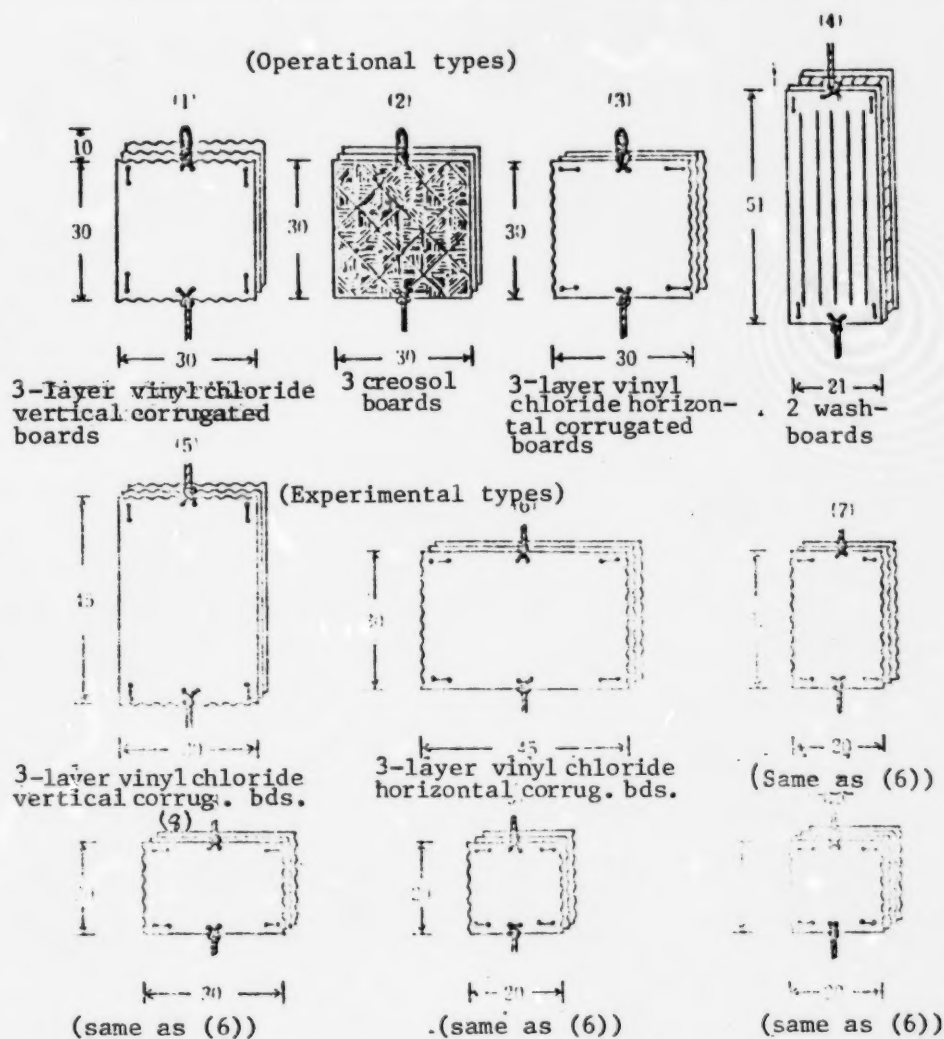


Fig. 10. Types and construction of seed collectors, 1978 (unit: cm)

Type IV: 36 suspended collection lines, 100 m long, 2.4 m apart.

② Streamer method (Fig. 12)

On a length from 5 to 50 m, collectors were placed at fixed intervals according to need, and testing was carried out at various depths and locations.

(3) Period of installation of collection facilities

Installations were created every year, principally from mid- to late September, but in 1975, to determine the relationship between period of installation

Fig. 11. Construction of urchin seed collection facility (fixed suspension type)

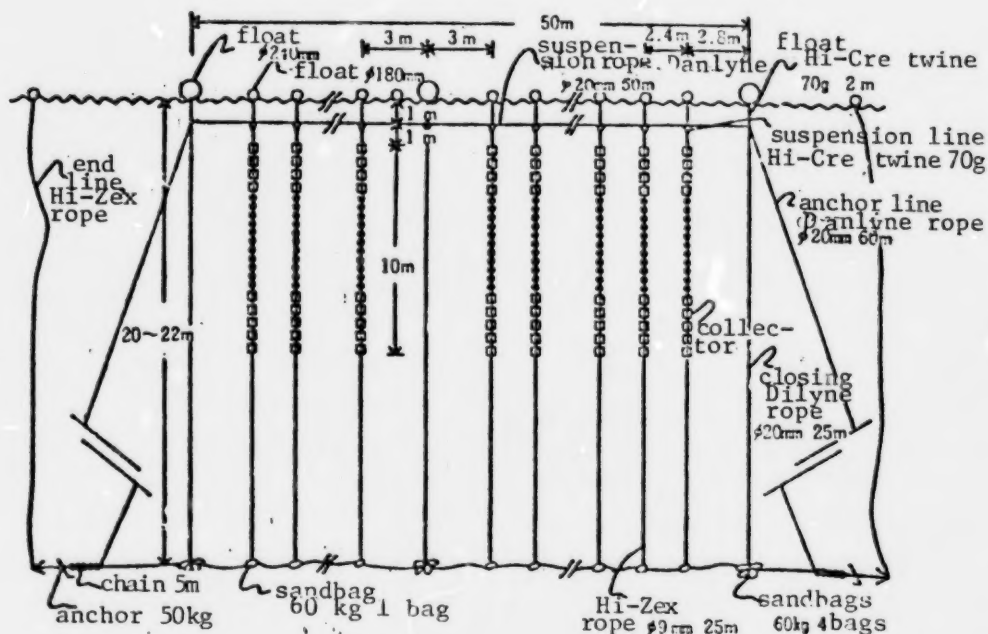
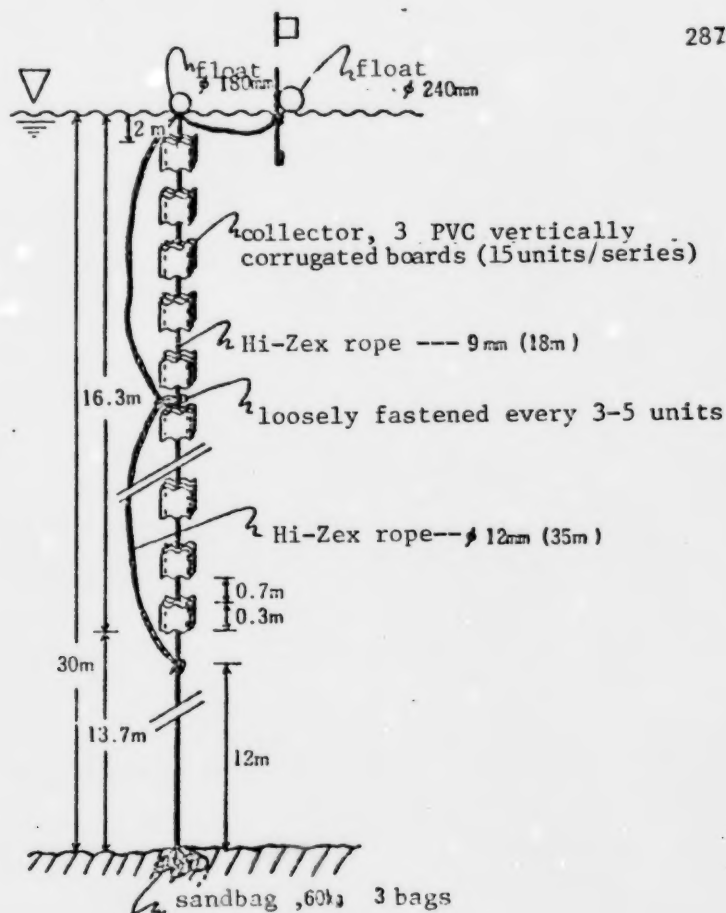


Fig. 12. Construction of
urchin seed collection
facility
(streamer type)



and numbers adhering, the operations were carried out in October and November as well.

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(4) Location of collection facilities

As shown in Fig. 1, facilities were installed in the coastal area from the east side of Cape Atsutoma on the coast of Mikuni in Shakotan, to Horomui. In 1978, for the sake of comparison with other maritime areas, streamer-type facilities were also installed in Furubira, Yoichi and Otaru.

As for water depth in the facilities, tests were made in a scope of 5-50 m between 1974-1976, and after 1977 the limit was set at 20-25 m.

2. Preservation of collection facilities

The streamer types set at a 5 m depth on the west side of Cape Atsutoma (1974) were all damaged and washed away.

Among the 19 streamer types set at 8-9 m depths in the same location (1974), only 3 remained until May of the following year.

Of the fixed suspension type set at 16 m in the same location (1975), some damage was observed to the creosol boards and tubes.

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At a 20 m depth, almost no accidents occurred to the fixed suspension type or to the streamers. However, in 1976, at a 50 m depth, the streamer type could not be recovered, owing to cut rope.

It seems that almost no problems exist for preservation of the present fixed suspension facilities, but further investigation is required for strength, operating efficiency, and economic capacity, on materials, methods of fixing, and scope.

3. Quality and construction of collectors, and adherence of urchins

Table 5 gives 1 example of numbers adhering, by quality and construction of collectors.

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Table 5. Variations in numbers adhering due to quality and construction of collectors

				1975	
Type	Configuration	No. of individuals	of m ²	Comparison of numbers adhering by time of establishment	
Suspended	Vinyl chloride corrugated board	1 sheet	1.3 ※	$\left. \begin{array}{l} \text{Oct. 16} \\ \text{Sept. 17} \end{array} \right\} \times 100 = 34\%$	
	"	2 sheets	99.4 ※		
	"	2 "	33.8 ○		
	ABS corrugated bd.	1 sheet	57.1 ※		
	"	2 sheets	85.4 ※		
	ABS flat board	1 sheet	27.7 ※		
	Concrete slab	1 "	30.6 ※		
	Drainboard sheet	1 "	37.9 ※		
	Washboard	1 "	225.2 ※		
Horizontal	Creosol board	1 "	191.1 ※		
	Vinyl chloride corrugated board	1 "	118.6 ※		
	"	2 sheets	217.0 ※		
	"	3 "	203.0 ※		
	ABS corrugated bd.	1 sheet	97.3 ※		
	"	2 sheets	111.8 ※		
	"	3 "	137.8 ※		
	Vinyl chloride flat bd.		227.4 ※	$\left. \begin{array}{l} \text{Nov. 12} \\ \text{Sept. 17} \end{array} \right\} \times 100 = 2.3\%$	
	"		5.3 △		
Tube	ABS flat board		173.2 ※	$\left. \begin{array}{l} \text{Nov. 12} \\ \text{Sept. 17} \end{array} \right\} \times 100 = 3.6\%$	
	"		6.2 △		
※ Established Sept. 17, 1975		○ Established Oct. 16, 1975		△ Established Nov. 12, 1975	

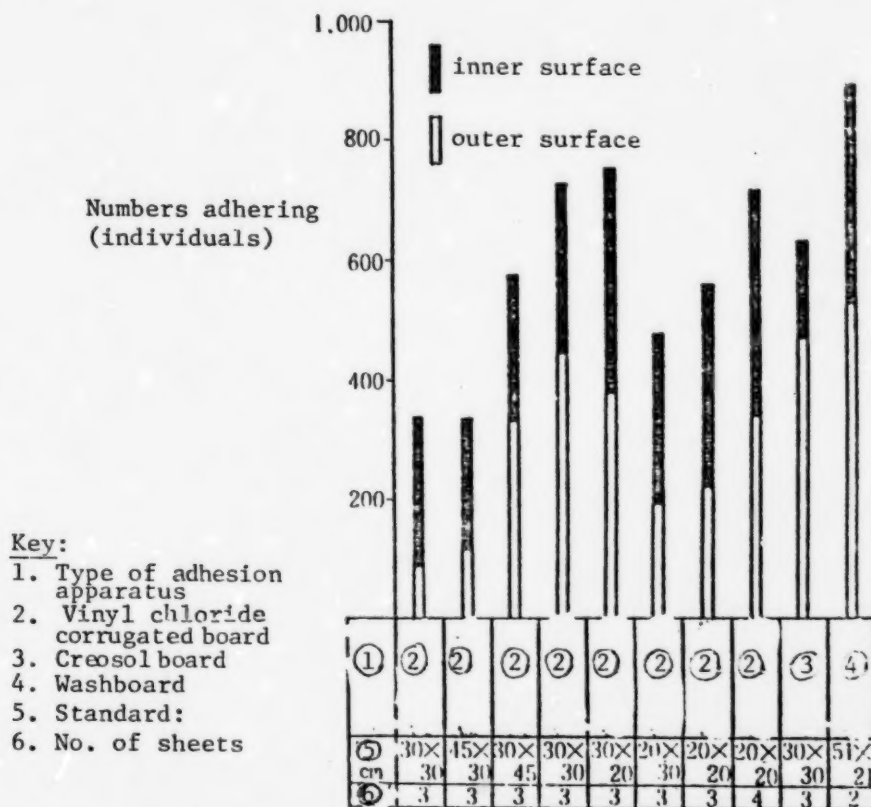
Young urchins adhered readily to hard materials like vinyl chloride resins, reclaimed plastic, etc., but almost not at all on Hi-Zex film, Netron netting, etc. Moreover, even vinyl chloride corrugated boards, placed in a pearl net, had adhesions on only 1/5 of the surface. In addition, only small numbers adhered even to hard materials such as black reclaimed plastic, yellow ABS, and concrete slabs.

As for collector construction, adhesion occurs more readily on bumpy surfaces rather than flat ones, so that for flat and corrugated boards of the same material, the corrugated type had twice as many adhesions.

On transparent vinyl chloride boards, adhesion was roughly equal for inner and outer surfaces, or else higher for the inner surface; in contrast, for the

washboard and cresol board, adhesion was greater on the outer surface and less on the inner (Fig. 13). It may be thought that the numbers adhering are great

Fig. 13. Numbers adhering to surfaces per 1 m^2



Feb. 5, 1979

for transparent materials, as light penetrates to the inner surface and adhering algae grow.

To consider variations in numbers adhering due to numbers of layers of boards: e.g. for vinyl chloride corrugated board (30 x 30 cm), Facility A, 1975, horizontal type, numbers adhering per 1 m^2 were: 118.6 individuals for 1 layer, 217 for 2, and 203 for 3, so that adherence was greater per unit surface for multiple layers (Table 5). Furthermore, on the vinyl chloride corrugated board (20 x 20 cm) suspended type, the 4-layer type had more adhesions than the

Table 6. Variations in numbers adhering, by direction of corrugations on boards, 1978

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		Atsutoma region per 1 m ²							
Survey date	material	Vinyl chloride boards (suspended type)							
	standard	30×30	30×30	45×30	30×45	30×20	20×30	20×20	20×20
	Layers	3	3	3	3	3	3	3	4
	corrugation	Vert.	Horiz.	Vert.	Horiz.	Horiz.	Horiz.	Horiz.	Horiz.
FEB. 5	Individuals adhering	178.7	333.4	179.7	273.5	369.5	252.1	297.0	368.8
	Rate %	100	186.6	100.6	153.0	206.8	141.1	166.2	206.4
MARCH 13	Individuals adhering	346.0	450.0	233.0	354.0	481.0	392.0	392.0	430.0
	Rate %	100	130.1	67.3	102.3	139.0	113.3	113.3	124.3

3-layer type (Table 6). However, for the large format 6- and 10-layer vinyl chloride boards (30 x 45 cm or 45 x 45 cm) tested in 1977, adherence to both the horizontal and suspended types was small.

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For numbers adhering according to vinyl chloride board size, per unit area in 1978, the 20 x 30 cm and 30 x 30 cm sizes were the greatest; per set, the 30 x 45 cm size was greatest, followed by 30 x 30 cm.

Comparison of suspended, horizontal and tube types shows no clear-cut variation by year, location or period, but numbers are greatest on the horizontal and tube types, and in the dropoff of urchins from March to May, they tended to be small for the horizontal and great for the tube type.

Comparison of numbers adhering on vinyl chloride corrugated boards (30 x 30 cm), suspension type, newly installed that year, and the type used the previous year, showed a tendency for the older type to attract the greatest amounts. Furthermore, there was a decided tendency for numbers to be greater for the horizontal rather than the vertical corrugated type (Table 6).

From the above results, no. (3), operational type in Fig. 10 is principally used at present. The board has a simple form, and when there are few adhering

organisms, the number of adhering urchins decreases sharply, and great amounts tend to fall off, so that it is desirable to make the form somewhat more complex.

4. Installation locations and urchin adhesion

Comparison of numbers adhering according to water depth of facilities in the coastal area of Cape Atsutoma (Table 7) shows that those at 8-9 m depth amount to 10% of those at 20 m. There was also a small percentage, 30%, at 16 m. Moreover, at 27-28 m, adherence was 35% greater than at 20 m, and in a scope up to 30 m, adherence was greater, the deeper the installations. 291

Next, for variations according to location of installations at the same depth of 20 m, comparison of Atsutoma, Takarajima and Shishizawa along the Mikuni coast showed that on vinyl chloride corrugated boards, numbers were greatest for 1976, 1977, 1980, 1981 and 1982 at Atsutoma, and for 1978 and 1979 at Shishizawa (Table 8).

Table 7. Variations in numbers of young urchins adhering, by depth of collection facilities

Year established	Water depth at facility	Type of collector	No. of urchins adhering per 1 m ² area	Year, month & date of survey
1974	8~9	2-layer vinyl chloride corrug. board	5.5	1975.04.17
	20	"	55.6	
1975	16	"	32.4	1976.05.11
	20	"	99.4	
1977	20	3-layer vinyl chloride corrug. board	198.7	1978.04.12
	27~28	"	269.4	

Table 8. Numbers adhering per set of collectors (3-layer vinyl chloride corrugated boards), by location of collection facilities

Year established	Atsutoma	Takarajima	Shishizawa	Year, month & date of survey
1976	86.1	58.3	—	1977.05.10
1977	138.1	126.5	111.6	1978.04.12
1978	61.8	81.3	86.3	1979.04.16
1979	588.7	194.7	654.1	1980.04.16
1980	84.1	58.2	37.4	1981.04.16
1981	271.9	—	80.3	1982.03.22
1982	131.0	—	84.2	1983.03.11

Table 9. Variations in numbers adhering, by location in Northern Shiribeshi, 1978

Survey Period		Atsutoma A	Furubira	Yoichi	Otaru
Jan.-Feb.	No. of individuals adhering	178.7	117.8	313.2	36.5
	Rate	100	65.9	175.3	20.4
April	No. of individuals adhering	114.4	159.3	179.5	59.8
	Rate	100	139.2	156.9	52.3
	$\frac{\text{April}}{\text{Jan.-Feb.}} \times 100$	64.0	135.2	57.3	163.8

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Also, when the region was expanded to consider towns and cities in Northern Shiribeshi, great variations were found on vinyl chloride corrugated board in 1978: if the rate for Atsutoma in April 1979 was 100, rates were 139 for Furubira, 157 for Yoichi and 52 for Otaru (Table 8).

From the above results, it may be judged that for location of collection installations, a scope of 20-30 m water depth is appropriate. However, even at the same depths, adherence is low in places where the currents are rapid, and also, since annual and regional variations are considerable, it is necessary to make surveys of the relationship between ocean conditions and appropriate regions.

5. Suspension depth of collectors and urchin adhesion

Figs. 14 and 15 indicate variations in numbers adhering according to depth of collection facilities installed at 20 m and 30 m in Atsutoma.

In facilities at 20 m, great numbers adhere in a scope of 2-3 m to 12-13 m depth, and in those at 30 m, adherence is great at the 5-20 m layers; in comparison with 20 m deep facilities, a tendency for adherence depth to be great was observed.

Adherence depth of metamorphosed urchins may be thought to be determined

by a combination of such factors as: free-swimming depth at the time the metamorphosed urchins approach the coast, insertion conditions of diatoms adhering to the collectors, and oscillation of collectors due to wave movement. However, actual conditions for these have yet to be elucidated.

6. Installation period and urchin adhesion

For numbers adhering to collectors installed on Sept. 17, Oct. 16 and Nov. 12, 1975, if the figure is 100 for September, it is 34 for October and 3 for November (Table 5), and amounts sharply decreased, the later the period. Organisms adhering to the collector surfaces decreased, the later the installation period.

Figure 14. Numbers adhering, by water depth (older vinyl chloride corrugated board, 3 layers, April 14, 1978)

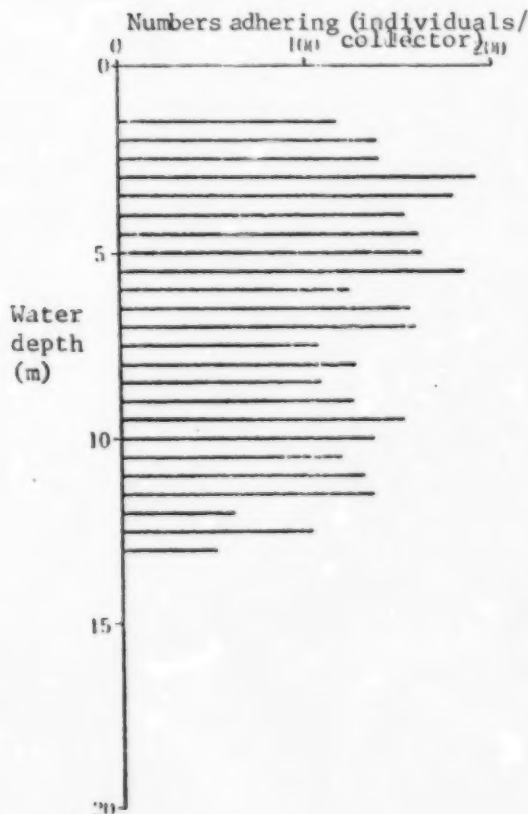
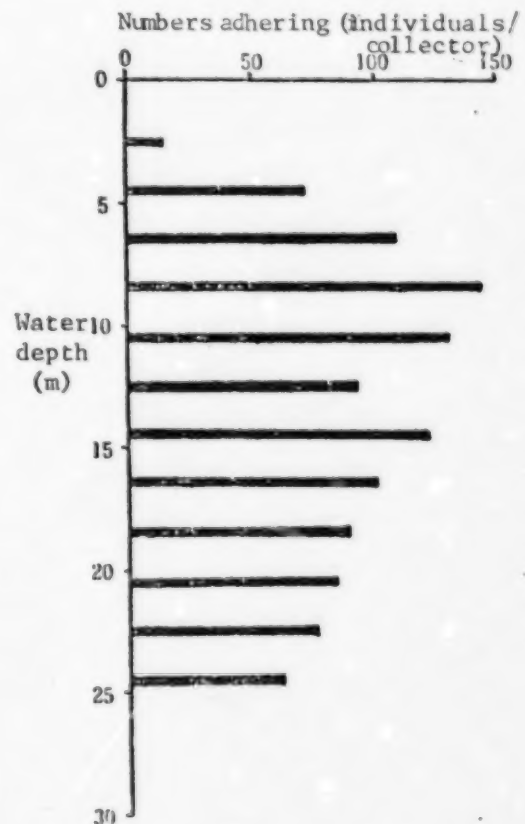


Figure 15. Numbers adhering, by water depth (streamer type vinyl chloride corrugated board, 2 layers, March 14, 1977)

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The decrease in amounts for the appearance of metamorphosed young urchins S. intermedius from late November to January perhaps shows that the formation of organisms accumulating on the collector surfaces is an important condition for adherence. In the maritime area of Shakotan, installations must necessarily be made in September.

7. Species of adhering urchins

The two species adhering to the collectors are S. intermedius and S. nudus, but the latter is extremely rare: 0% in 1974, 7.4% in 1975, 0.3% in 1976 and 0% in 1977 and 1978.⁴⁻⁶

Free-swimming larvae of S. nudus virtually do not appear after November; moreover, since individuals in the metamorphic stage are not collected (see Table 1), it may be supposed that they settle on the ocean floor directly after metamorphosis in October-November, and seed collection in large amounts is no doubt difficult.

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8. Growth of adhering urchins

The shell diameter of adhering urchin S. intermedius is under 1 mm in January, and 1-3 mm in March; in May the range is from 1 to 10 mm, and individual differences become considerable; many 1-5 mm diameters were observed. The growth of urchins adhering to collectors is somewhat faster than that of urchins in natural fishing grounds.⁴⁻¹⁰

As for S. nudus, the small numbers make it difficult to judge, but growth appears to be ^{somewhat} more rapid than for S. intermedius.

9. Periodic and annual variations in adhering urchins

Table 10 indicates adherence according to year and period, per set of vinyl chloride corrugated boards.

Table 10. Numbers adhering per set of collectors, by year

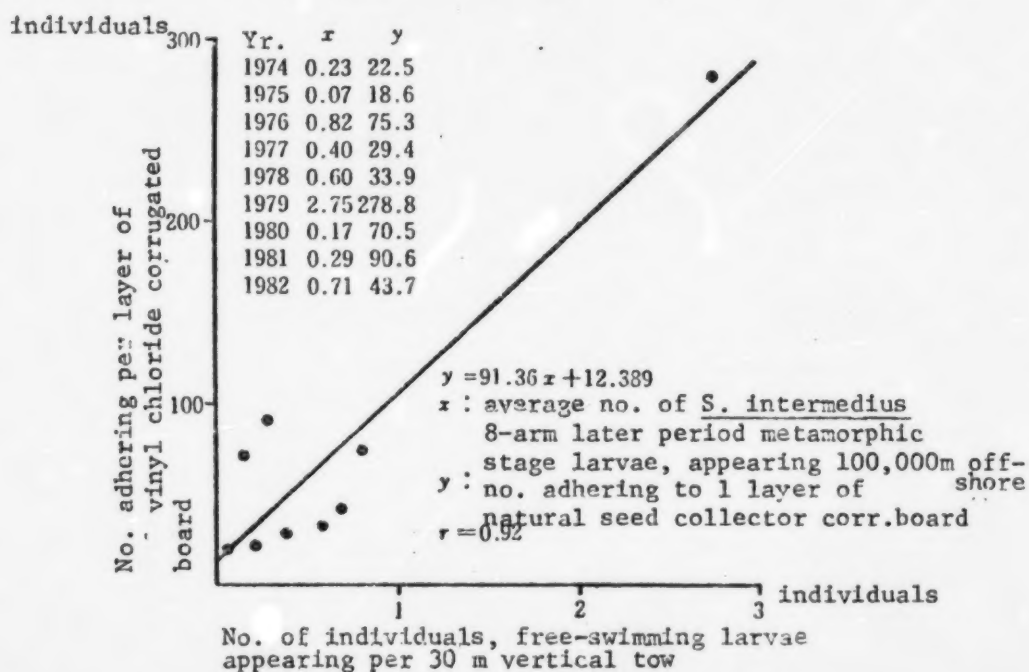
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		(3-layer 30X30cm) Atsutoma									
Survey period	Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Jan.-Feb.		67.5	55.8	225.9	88.2	101.7	836.4	211.5	148.1	—	41.6
March-April		30.0	67.5	277.5	166.5	186.9	588.6	106.5	271.9	131.0	—
April-May		29.7	53.7	103.2	120.6	61.8	507.6	84.0	—	—	—
April-May, March-April	x100	99.0	79.6	37.2	72.4	33.1	886.2	78.9	—	—	—

In January-February, the values for 1979 were the highest, and for 1975, the lowest. In March-April, except for 1974, 1979 and 1980, adherence increases; this is perhaps because in January-February the urchins are small and sometimes overlooked, and because few of them fall off or die. Fig. 16 shows the relationship between numbers of larvae appearing in December and numbers adhering to collectors. In general, a correlation was observed; in particular, until 1979, there was a high correlation of 0.98. However, after 1980 there is great dispersion and almost no correlation is observable.

Table 16. Relationship between numbers of free-swimming larvae appearing and adhering in the Atsutoma region

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In April-May for all years, the number of individuals decreased. The rate 294
 varied annually; dropoff was especially pronounced in 1976 and 1978. Small ur-
 chins up to a shell diameter of about 3 mm did not readily fall from the 295
 collectors, but above that size, many dropped off by the mere action of removal
 of collectors from the water. The large dropoff number is no doubt due to the
 oscillation of collectors when wave movement increased.

To prevent dropoff, 3 methods may be considered. (1) The construction of
 the collector should make dropoff difficult. In the 1976 results, maximum drop-
 off was from the flat-sheet tube type, and the minimum from the horizontal type.
 However, even for the latter, more than 50% fell off compared to March, and at
 present, complete prevention of dropoff through improved construction seems
 difficult.

Method (2) is to recover seeds by hoisting collectors before dropoff oc-
 curs. In this case, since the seeds are small, it is necessary to establish a
 method of intermediate culture until release.

Method (3) is to increase depth of installations and of ropes, to minimize
 oscillation of collection facilities by wave movement. However, testing on
 this point has not yet been carried out; it should be in the future.

10. Relationship between material adhering other than urchins, and numbers

Material adhering to collectors may be divided into animal and plant
 matter, and sandy mud.

Among animal materials are many with adhesion properties: Hydrozoa,
 Polyzoa, Spirorbis foraminosus, Hydroides, and barnacles, as well as ascidi-
 ans, etc., and skeleton shrimp, lugworms, etc., were numerous among those
 on the surface. Many ascidians gather in colonies on collectors other than
 vinyl chloride corrugated boards, and sometimes cover the entire surface, so
 the greater the covered surface area, the fewer the adhering urchins. More-
 over, variations were observed according to year and location.

Among plant materials were adhering diatoms, sea lettuce, kayamonori, fukuronori, and seiyobabanori lavers, kelp (Laminaria japonica), wakame seaweed, and kiburiitogusa (Polysiphonia spp.); amounts tended to decrease in shallower water.

Few urchins adhered to the inner surface of boards impervious to light, such as creosol and washboards, on which almost no diatoms adhere. In addition, only a small number of organisms including diatoms adhered when the installation period of collectors was after October.

Even if some amounts of sandy mud adhered, they seemed not to affect the adherence of urchins. However, in 1974, great amounts of sandy mud adhered to diatoms growing on the surface of collectors at 8-9 m depth, and almost no urchins were seen. Moreover, on the horizontal type, sandy mud adhered in the furrows of the corrugations, and diatoms did not grow sufficiently, so that urchin growth was often extremely defective.

It is well known that metamorphosed young urchins react to biological substrates such as adhering diatoms and bacteria film, and select sandy settling places.^{12,22} Furthermore, the growth of young sea urchins is strongly influenced by feeding conditions, so that it is extremely important to form colonies of organisms favorable to settling and growth. On the other hand, as the example shows, there are cases when the collector surfaces are occupied, impeding urchin settlement, and it is therefore necessary to consider composition and numbers of colonies of organisms formed on the surface.

11. Estimated numbers adhering, by year

Table 11 indicates the numbers of collection facilities and estimated numbers adhering, after 1976. Numbers of individuals were: 1976 - about 100,000; 1977 - 330,000; 1978 - 430,000; in 1979, at 4 million, there was a significant increase, and in 1981 and 1982 as well, the figure exceeded 1 million, and while annual variations were indicated, seed collecting operations developed greatly. In the future it will be important, while raising the

Table 11. Results of urchin natural seed collection and intermediate culturing operations, by year

Year	No. of collection facilities		Number of seeds collected		No. of intermed. culture facilities		No's by intermed. culture	No's naturally fallen & released	Total released	Notes
1976	50m	4	100,000	50m	1		70,000	30,000	79,000 (49,000)	Between parentheses: intermediate culture component
1977	50m	9	330,000	550m 100m	1 2		50,000	280,000	317,500 (37,500)	
1978	50m 100m	7 3	527,000	100m	5		250,000	277,000	368,000 (162,500)	
1979	50m 100m	10 6	4,000,000	50m 100m	1 6		750,000	2,576,000	3,095,000 (525,000)	
1980	100m	12	624,000	110m	11		624,000	—	(450,000)	
1981	100m	15	2,057,000	110m	17		2,057,000	—	(984,600)	
1982	100m	19	1,387,700	110m	17		1,387,700	—		
TOTAL			9,025,700				5,188,700	3,163,000	5,698,200	

minimum limit of numbers collected, to make renewed efforts to establish and improve collection techniques with higher operating efficiency and economy.

III. Experiments on intermediate culture of urchin seed

Intermediate culture experiments were carried out first in the sea, from 1976, and testing on improvement of culturing baskets, as well as feed and collection density was performed. In 1979 and 1980, detailed experiments on feed and collection density were carried out onshore, in water vats at the Hokkaido Institute of Mariculture. Again, from 1981, for the sake of developing intensive intermediate culturing techniques ^{in on-shore facilities,} testing was carried out on culturing facilities, period of commencement of culturing, and collection density. Tables 12 and 13 offer a summary of the test results.

1. Culturing facilities and culturing baskets in the sea

Fig. 17 indicates culturing facilities. For baskets, since 1979, a Tri-cal net basket (80 x 80 x 40 cm), mesh 2.8 mm, has been used, and in 1982 and 1983, to prevent dropoff of small urchins, 1-2 mm mesh baskets were compared.

In the 1982 results, the highest rate was for 1 mm mesh Turbo screens, but in 1983, no great discrepancy by mesh was observed (Tables 14, 15).

Table 12. Results of intermediate culture in sea

Yr.	Culture period	Feed	Culture basket	1.	2.	3.	Survival rate	Notes
	No. days		diam. height	Indi-vids	mm	mm	%	
1976	1976.6. 4~ 11.18(180)	①	PVC 53cm 32cm	826	4.7	15.3	66.8	
1978	1978.6. 5~ 10.31(149)	② ③ ①	PVC .63cm 32cm diam. height	300	6.3 6.5 5.9	13.4 22.5 17.1	11.3 19.0 22.7	
					6.0	11.8	2.7	
	1979.6. 4~ 10.24(142)	①	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	15.1 15.6 17.2	36.0 31.0 7.0	Intermediate measurement carried out
	1979.6. 4~ 9. 4(93)	Other algae	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	(11.7) 13.7 11.2	(88.0) 27.0 25.0	Cause: basket outflow
		③	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	16.6 13.4 (13.5)	67.0 50.0 (61.0)	
		Other wild grasses	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	15.9 14.9 16.3	53.0 34.0 20.0	"
1979	1979.6. 4~ 10.26(144)	①	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	13.2 14.6 14.3	52.0 51.0 32.0	No intermed. measurement
		Other algae	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	14.0 13.8 —	77.0 77.4 —	Cause: basket outflow
		③	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	— 13.3 13.0	— 76.0 65.3	"
		Other wild grasses	2-flap lid 2.8 mm mesh 50×50×25cm	300 500 700	6.2 6.2 6.2	15.0 14.0 12.8	68.0 62.0 53.0	
	1980.6. 9~ 10.7(120)	③	Fastener lid 2.8 mm mesh	1,000	6.3	17.4	86.3	
	(1980.6. 9~ 9. 8(92))		80×80×40cm	1,500	6.0	(16.3)	(77.9)	Cause: basket outflow
				2,000	5.0	13.3	84.6	
	(1980.6. 9~ 7.10(32))			2,500	4.7	(9.2)	(82.4)	Cause: basket outflow
1980	(1980.6. 9~ 9. 8(92))			3,000	5.0	(10.4)	(77.6)	"
	(1980.6. 9~ 9. 8(92))	①		1,000	6.1	(13.7)	(67.3)	"
	1981.7.15~ 10.1(78)	③	Fastener lid 2.8 mm mesh	1,000 2,000	10.4 12.5	13.5 —	93.5 —	Cause: basket outflow
1981			80×80×40cm	3,000	9.6	16.4	46.1	
				4,000	10.5	15.5	66.2	
	1982.6.11~ 8.20(70)	③	Fastener lid 2.8 mm mesh	2,000 3,000	5.5 5.3	9.1 8.7	92.3 37.8	
1982			80×80×40cm	4,000	5.8	10.4	41.3	
				5,000	4.8	9.6	37.0	
	1983.6. 9~ 10.5(118)	③	Fastener lid 2.8 mm mesh	2,000 3,000	7.0 5.6	14.1 13.8	54.8 47.7	
1983			80×80×40cm	4,000	6.2	—	—	Cause: basket outflow
			Fastener lid 1.0 mm mesh 80×80×40cm	2,000	7.1	14.0	66.7	

Key to Table 12: ① Kelp, *Laminaria religiosa*
 ② Butterburr, *Petasites japonicus* var. *giganteus*
 ③ Knotwood, *Polygonum sachaliense*

1. collection density
2. average shell diameter at beginning of culture
3. average shell diameter at end of culture

Table 13 Results of intermediate culture on land

year	culture period	feed	culture basket	3.	1.	2.	survival rate	Remarks
年度	育成期間	飼料	育成籠	収容 密度	開始時 直径	終了時 直径	生存率 %	備考
1979								
	7. 2~③	オオイタドリ	12 L プラスチック	38	10.4	19.2	81.6	道立校
	11. 1(122)	マコンブ	角型水槽	38	10.8	18.4	73.7	培養セ
	①	オオバコ		40	10.6	20.1	72.5	ンター
		無給餌④		41	9.9	15.4	68.3	
	1979. 6. 27~③	オオイタドリ	50×50×50cm	300	5.6	13.4	87.0	道立校
	11. 1(127)	マコンブ②			6.0	10.2	65.3	培養セ
		オオバコ①			6.0	11.8	79.0	培養セ
		無給餌④			6.2	9.5	86.3	ンター
1980								
	1980. 6. 5~	オオイタドリ	80×80×40cm	1,000	5.3	15.6	38.4	道立校
	10. 3(120)		海中中間育成用	1,500	5.7	14.8	40.1	培養セ
			籠	2,000	5.4	13.5	43.0	培養セ
				2,500	6.2	12.6	37.9	ンター
	③	オオイタドリ	80×40×40cm	500	6.6	12.9	59.8	
		80g/week						
		250g/week			6.9	15.2	52.6	
	③	オオイタドリ	80×40×40cm	750	5.3	12.3	43.6	
		120g/week						
		250g/week			5.1	12.0	80.0	
	③	オオイタドリ	80×40×40cm	1,000	4.7	12.3	64.0	
		250g/week						
	④	無給餌			4.8	6.9	43.3	
	③	オオイタドリ	80×40×40cm	1,250	4.5	12.0	60.6	
		250g/week						
	④	無給餌			4.6	7.4	34.3	
	③	オオイタドリ	80×40×40cm	1,500	4.8	12.4	37.4	
		250g/week						
	②	マコンブ	80×40×40cm	500	4.4	10.2	86.8	
		230g/week						
1981								
	1981. 6. 29~③	オオイタドリ	70×90×40cm	2,000	12.1	14.1	—	予備
	8. 19(51)			3,000	10.8	13.9	—	試験
				4,000	11.0	12.9	—	
				5,000	11.5	13.5	—	
				6,000	11.1	14.4	—	
	1981. 8. 21~③	オオイタドリ	70×90×40cm	2,000	13.8	15.2	48.5	
	9. 30(40)			2,500	13.5	14.8	52.9	
				3,000	12.4	15.1	54.2	
			70×90×40cm	250	19.3	21.8	72.4	
			大型群	500	20.2	21.7	77.8	
1982								
	1982. 6. 15~③	オオイタドリ	70×90×40cm 屋外	2,000	6.4	14.4	56.8	
	8. 19(65)			3,000	5.5	11.9	43.9	
				4,000	6.2	12.4	38.8	
				5,000	5.5	11.4	39.1	
			70×90×40cm 屋内	4,000	5.2	13.2	39.2	
	1982. 8. 23~③	オオイタドリ	70×90×40cm 屋外	2,000	11.8	13.8	67.7	
	10. 12(50)			3,000	11.4	13.5	48.7	
				4,000	11.7	13.2	49.8	
				5,000	11.2	12.6	39.3	
			70×90×40cm 屋内	4,000	11.9	13.4	57.2	
1983								
	1983. 6. 9~③	オオイタドリ	70×90×40cm	2,000	7.1	15.8	53.5	毎月測
	10. 5(118)			3,000	7.3	14.3	43.3	定
				4,000	6.4	15.4	25.5	
				2,000	7.0	14.7	72.7	無測定
				3,000	7.2	14.6	49.5	
				4,000	7.3	14.2	37.9	

① plantain

② makonbu kelp (*laminaria japonica*)③ kelp (*laminaria religiosa*)

4 no feeding

1. average diameter at start of culture

2. average diameter at end of culture

3. collection density

a. 12 L plastic polygonal water tank

b. basket for intermediate culture in the sea

c. large type group

d. 100 % damage at time culture started

e. outdoors

f. indoors

g. Prefectural General Center for Culture Fisheries

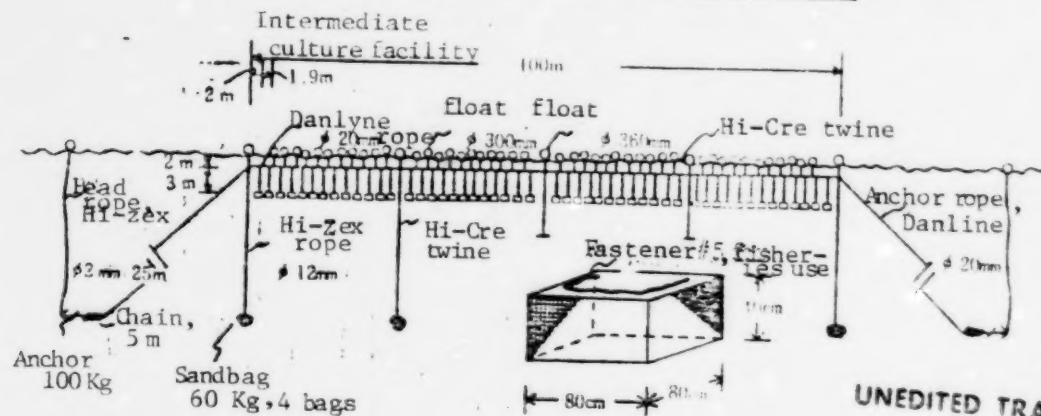
h. preliminary test

i. proportion of damage at end of culture

j. measured each month

k. no measurements

Fig. 17. Structure of intermediate culture facility



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Table 14. Experiments in dropoff prevention in sea, 1982

Date of collection & amounts	Basket type	Basket, No. of individuals	Basket, exterior Mean diam-eter	Adherence to collector, No. of individuals	Basket, interior Mean diam-eter	Basket, interior No. of individuals	Total	Ratio
1982.2.17	Turbo screen 2%	60	2.84 ± 0.69	2.6	1.479	4.22 ± 1.19	798	5.24 ± 1.50
Amts collected	" 1%	54	4.31 ± 1.59	1.3	2.918	3.51 ± 1.12	1,283	4.67 ± 1.91
149.06 individuals	Strong Tetro-ron 1% Turbo 2%	—	—	2.352	4.01 ± 1.42	771	4.86 ± 1.67	100.0
2.3% indiv.	Strong Tetro-ron 1%	—	—	0.4	2.009	4.03 ± 1.26	1,595	4.16 ± 1.35
(Per basket)	Tri-Carb. net 2.8%	207	2.42 ± 0.52	9.1	1.292	3.18 ± 1.09	769	5.63 ± 2.42
(previous type)	Turbo screen	54	3.17 ± 0.93	1.8	1.668	4.22 ± 1.45	1,238	5.37 ± 1.65
1982.3.21	" 1% Turbo 2%	137	4.21 ± 1.24	2.7	2.771	3.44 ± 1.43	2,216	5.08 ± 1.65
Amts collected	Strong Tetro-ron 1% Turbo 2%	—	—	1.3	1.435	3.96 ± 1.45	819	4.53 ± 2.09
271.86 individuals	Strong Tetro-ron 1%	—	—	2.6	2.670	3.46 ± 1.52	1,645	4.38 ± 1.56
5.43% indiv.	Tri-Carb. net 2.8%	196	3.41 ± 0.88	7.4	1.118	3.77 ± 1.41	1,310	—
(Per basket)	(previous type)	—	—	—	—	—	92.6	2.623

Figures () : rates from numbers adhering in March

Table 15. Experiments in dropoff prevention in baskets in sea, 1982

Collection date & amounts	Basket type	Collectors	Basket, interior individuals	Totals		Basket, exterior Rate
				No. of individuals	Mean shell diameter	
1983.3.11	Previous type	1,535	1,167	2,702	5.95 ± 2.25	103.1
indiv. sets	Tri-net 3mm mesh	1,950	1,185	3,135	5.69 ± 1.77	119.7
131 × 20	Turbo screen 1 mm mesh basket	1,720	993	2,718	4.5 ± 1.75	103.7
2,620 indiv.	Turbo screen 1 mm mesh, 2 layers	—	—	—	—	—

Moreover, culturing was carried out in 1983 until October in 1 mm mesh baskets, but there was almost no difference in growth or survival rates, from use of the 2.8 mm baskets (Table 16).

Each basket is of such a size that it holds exactly 20 seed collectors; handling is easy, and at present there is probably no need to make changes in size. Use of the 1 mm mesh size permits urchin dropoff. The results of 1983 showed natural decrease in summer to be low. However, since the summer of 1983 had unusually low temperatures, there should be verification at times of high temperatures.

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2. Time of commencement of culture in the sea and culturing methods

Since young urchins adhering to collectors drop off in April-May, they must be collected before that time in intermediate culture baskets. Moreover, if the period is too early, the urchins are small and many escape from baskets, and also, amounts of seaweed inserted in collectors are low, so that feed becomes insufficient in a short period after commencement of culturing. In previous experimental results, in late March, 20 sets of collectors were accommodated as they were in the culturing baskets, and left till early June. The feed adhering to the collectors disappeared, and at the stage where seeds grew to about 5 mm shell diameter, collectors were removed and there was no particular problem in using the culturing method by beginning feeding supply. However, for thorough

Table 16. Daily amounts of feed, by type of feed

Type	1979. July 2-Aug. 3			Aug. 4-Sept. 7			Sept. 8-Nov. 1								
	Amt. of intake	Daily intake/100 individs.	Daily intake/100 g of weight	Amt. of intake	Daily intake/100 individs.	Daily intake/100 g of weight	Amt. of intake	Daily intake/100 individs.	Daily intake/100 g of weight						
	g	%	%	g	%	%	g	%	%						
	62.6	6.52	100	5.87	100	154.0	15.17	100	7.12	100	314.0	20.39	100	6.01	100
	23.1	2.26	34.7	1.85	31.5	117.4	10.82	71.3	5.03	70.6	160.0	9.38	45.0	2.41	40.1
	95.2	10.24	157.1	7.16	122.0	169.8	16.17	106.6	5.67	79.6	241.0	21.38	104.9	5.37	89.4

*Method for feeding

1 wild grass, immersion in sea water→
removal of sea water→wiped with cotton or towel.
Weighing→dosage.

prevention of dropoff, it would be preferable to hasten the collection period. Feeding from June results, in many experiments, in a mean shell diameter of about 15 mm in October, and it is possible to culture urchins to release size in a feeding period of 5-6 months.

3. Types of feed at sea and amounts administered

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In the Mikuni maritime region, in the June to October period of urchin seed intermediate culture, only small amounts of algae grow, beginning with kelp, so that they are difficult to secure for feed. Thus, feed experiments were performed with leaves of knotweed (Polygonum sachaliense) and other plants which were relatively easy to obtain.

The daily intake rate for knotwood was about 2-5% of the weight, and although this was about one-half the value for kelp (Table 16), growth was faster than for kelp in almost all the tests. In addition, growth by knotweed feeding tended to be more rapid, the smaller the urchin, and above a shell diameter of 15 mm, almost no difference from kelp was observed.

As for amounts administered, urchin growth was promoted by doubling the weekly amount considered strictly necessary.

Table 17 presents the results of analyzing the components of knotweed.

Table 17. Results of analysis of carbon and nitrogen in knotweed

May-August 1980							
Year, month & date	No. of specimens	Wet weight	Dry weight	Rate(%)	Car- bon(%)	Nitro- gen(%)	Carbon/ nitrogen
1980.5. 26(A)	11	8.55±24.12	2.42±0.366	29.70±6.350	45.96±1.342	5.82±0.703	7.98±0.778
(B)	8	4.76±0.971	1.87±0.159	40.01±4.900	45.72±4.225	5.73±0.908	8.06±0.720
(C)	9	62.2±1.314	2.10±0.282	34.57±4.527	45.87±1.607	5.35±1.100	8.90±1.762
Total	28	6.72±2.345	2.15±0.365	34.21±6.846	45.86±6.846	5.64±0.896	8.30±1.206
6. 23(A)	12	12.10±1.571	2.21±0.573	18.03±3.130	45.81±1.539	3.48±0.608	14.62±7.169
(B)	12	8.15±2.656	1.58±0.603	19.04±2.107	46.51±1.846	4.26±0.804	11.43±2.212
Total	24	9.71±3.594	1.89±0.660	18.53±2.659	46.16±1.700	3.87±0.883	13.02±5.438
30 days after freezing							
7. 23(A)	16	8.49±2.047	1.13±0.333	13.38±2.991	45.81±0.913	5.31±0.346	8.65±0.473
(B)	10	8.72±2.777	2.24±0.756	25.63±1.699	46.69±0.589	3.23±0.148	14.47±0.670
(B)	16	8.11±2.760	2.05±0.745	25.42±3.564	46.63±1.210	2.93±0.229	16.03±1.552
II	26	8.34±2.728	2.12±0.771	25.50±2.988	46.65±1.002	3.05±0.249	15.43±1.485
8. 25(A)	10	8.88±2.838	2.63±0.826	29.85±2.152	42.70±1.983	2.87±0.266	13.81±1.220
(B)	10	11.45±1.971	3.23±0.520	28.41±2.871	47.14±3.940	3.45±0.282	13.67±0.733
Total	20	10.16±2.719	2.93±0.738	29.13±2.577	44.92±3.743	3.28±0.319	13.74±0.982
90 days after freezing	20	8.11±2.268	1.06±0.274	13.49±3.350	46.49±1.101	5.85±0.338	7.97±0.521

Leaves from knotweed grown on the grounds of the Central Fisheries Experimental Station were gathered, once a month from May to August, about 20 leaves per month. Each leaf was weighed, then dry-weighted after 48 hours at 80°C, and the rates were obtained. Analysis of carbon and nitrogen was carried out by the usual methods by a CN coder (MT-500) from the Yanagimoto Company. The leaf weight (wet weight included) varies according to leaf position. In every month leaves in intermediate position show high values, but in June, high values were indicated for leaves closer to the tip. However, for dry rates in every month, the closer the leaves are to the tip, the higher the values tend to be. Considered by month, the rates for June lower to about one-half of those for May, but afterwards they increase until August. Nevertheless, values are lower than for August and May. For carbon values, there are some variations according to the leaf, but from May to August, at 45-50%, there was no particular tendency according to month or position. 303

Changes in nitrogen values were observed, according to leaves. In both May and June they were higher at the tip and lower at the base. In addition, all other nitrogen values after June were about 2% lower than for May. Moreover, when leaves were gathered on May 26 and frozen for storage for 30 and 90 days at -25°C, then analyzed in the same manner, the results were: dry rate for knotweed was 13%, or 20% lower than the ^{34% yield} of fresh leaves. However, almost no change from May occurs for carbon and nitrogen.

From the above results, it was determined that for seeds with 5-15 mm shell diameter, knotweed leaves can be sufficiently used as feed. In addition, in actuality, by freezing and storing large amounts of knotweed leaves, intermediate culture of large amounts of seeds became possible.

4. Collection density during culturing in sea

In urchin growth, according to almost all experiments, there was a tendency for growth to be slow the higher the collection density, and for the survival

rates to lower as well. In a basket 80 x 80 x 40 cm, the number accommodated was 2,000, and in many cases good results were obtained; in some, the survival rate reached 80-90%.

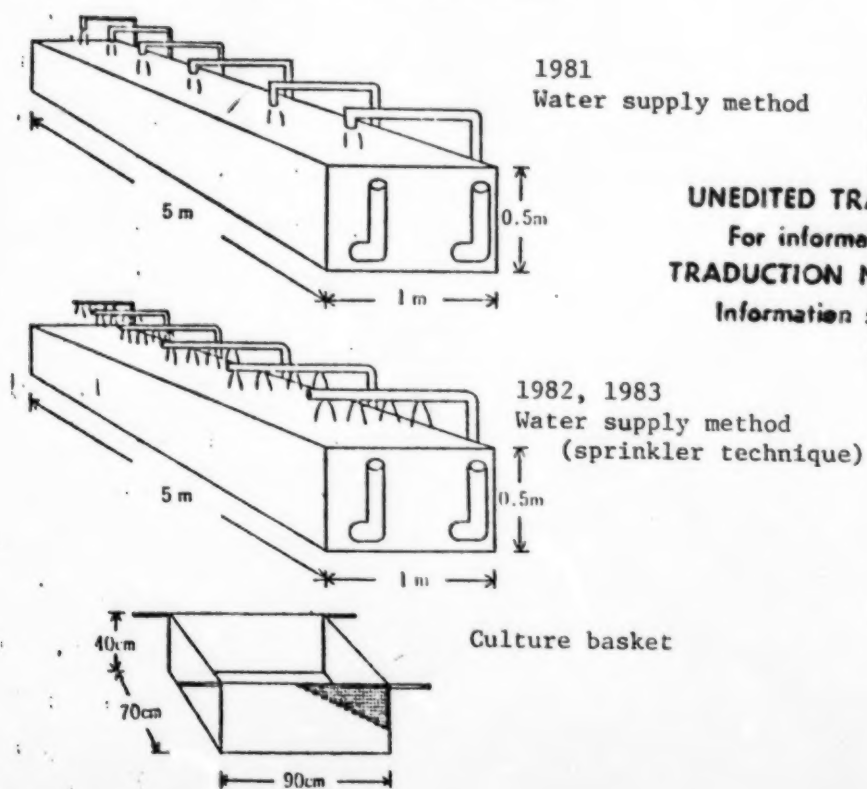
For an appropriate collection density, determination is made by growth and survival rates in culturing, and these may be thought to be influenced by that year's natural environmental conditions and feed administration control. In particular, in years when summer water temperatures continue to be above 22-23°C, it is particularly necessary to be attentive to administering culture, including collection density.

5. Onshore intermediate culturing facilities

The water vats used were 5 m x 1 m x 0.5 m. The culturing baskets were 90 x 70 x 40 cm, the size to hold 20 sets of collectors, of Trical net 3 mm mesh; they were suspended in the vats on vinyl chloride pipes (Figure 18).

The water supply was by the shower method, from above each basket. The 1 mm 304

Figure 18. Construction of outdoors water vats and culturing baskets



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mesh for baskets was found to be unsatisfactory, as it caused blockage.

Since urchins produce great amounts of excreta during culturing, and these decay, leading to deterioration of water quality, a structure permitting excretion naturally to the exterior of the vats is necessary.

Water quality management in onshore vats is the most important point in culturing.

The water inlet requires a construction and location so that fresh water, as from rivers or rain, will not flow in, and which will not be submerged by drifting sand.

As for the water supply, it is desirable to sprinkle for each basket, in order to improve the circulation of the water inside the baskets. In addition, the amount of water supply, according to growth conditions, should be given some margin to allow variation to occur.

For mesh used in the culturing baskets, the 1 mm type causes water quality to deteriorate because of sediment such as mud; the 3 mm type is unfavorable to sediment of this type, and also, the rate is over 90%, so that 3 mm mesh is preferable. Furthermore, there are cases when it becomes necessary to enlarge the mesh, in response to urchin cultivation. 305

6. Period of commencement of intermediate culture, onshore

Table 18 presents results of accommodating collectors, on February 17, and March 23, 1982. The ratio from numbers adhering to collectors was over 60% in the February collection, but under 10% in March. In March, large amounts of kelp adhered to the collectors, deteriorating the water environment of the baskets.

The period of accommodation of collectors is good before urchin dropoff begins, and an appropriate time is from late February to early March, when kelp growth is small.

Table 16. Intermediate culture experiments in early phase of breeding onshore, 1982 306

Measured June 3, 1982

Numbers adhering to collectors	No. of in- dividuals	Mean shell diameter	Interior of basket		Total	Rate	Collection date and amount	Basket type	Exterior of basket		Between exterior and interior of basket					
			No. of in- dividuals	Mean shell diameter					No. of in- dividuals	Mean shell diameter	No. of in- dividuals	Mean shell diameter				
3,084	4.24 ± 1.44	1,172	4.14 ± 1.13	91.5	4,653	157.1 (85.6)	1982.2.17	Outdoors	97	4.40 ± 1.40	2.1	300	4.79 ± 1.39	6.4		
3,565	—	1,081	—	84.6	5,491	185.4 (101.0)	Antigec- fed dividuals	Turbo screen	1%	300	—	5.5	545	—	9.9	
2,726	5.09 ± 1.23	927	4.57 ± 1.36	86.9	4,202	141.9 (77.3)	148.05 in- dividuals	Outdoors	549	4.05 ± 1.01	13.5	—	—	—	—	
3,018	—	1,158	—	84.9	4,918	166.1 (96.5)	2.87% dividuals	Trical net	742	—	15.1	—	—	—	—	
3,008	3.58 ± 1.20	1,070	6.12 ± 1.45	88.4	4,611	155.7 (85.7)	2.981 in- dividuals	Indoors	207	3.40 ± 0.76	4.5	326	4.21 ± 1.16	7.1	—	
2,829	—	598	—	98.5	3,480	117.5 (64.0)	(per bag)	Turbo screen	1%	9	—	0.3	44	—	1.3	
477	5.74 ± 1.52	54	7.10 ± 3.30	100	531	9.8	1982.3.25	Outdoors	0	—	—	0	—	—	—	
229	—	27	—	100	256	4.7	Antigec- 140.06 in- dividuals	Turbo screen	0	—	—	0	—	—	—	—

Between (): rates from numbers adhering in March

7. Collection density in intermediate culture onshore

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In experiments from 1982, collection of 2,000 individuals per basket was a result better than for high density, along with growth and survival. In 1983 experiments, collections were 2,000, 3,000 and 4,000, and practically no growth was observed, but the survival rate was as high as low density.

It is no doubt possible to thin out gradually the individuals which have reached a shell diameter over 15 mm, and to increase numbers collected by improving general techniques of management of water quality and amounts of feed administered. It is also necessary to respond to changes in seed size, and to investigate collection densities.

The advantages and disadvantages of culturing at sea or onshore may be expressed generally, as in Table 19. Sufficient investigation of the respective fishing ground environments and of social environments will permit judgment on the appropriate method to use.

Table 19. Comparison of urchin seed intermediate culture in sea and onshore

Conditions	Onshore	In sea
Preservation of facilities	Easy	Danger of damage by waves
Management of culturing	Can be done intensively, with few personnel members	Intensive management is difficult
Construction costs of facilities	High	Low
Maintenance costs	High	Often low
Culturing environment, e.g. water temperature and quality	Apt to become unstable, but artificial control is possible	High stability, but artificial control is difficult
Stability of seed (health)	If control is deficient, apt to become weak	Healthy in many cases

IV. Surveys on effectiveness of release

Release effectiveness surveys, combining various testing areas such as release methods and periods and size of released seeds have been implemented since 1976. Natural falling release, by which collectors having natural urchins (shell diameter 2-4 mm) are set in maritime release areas, and by which the urchins naturally fall off and disperse, was implemented in April and May from 1977 to 1979. Moreover, after young urchins naturally collected were cultured onshore or at sea, intermediate culture release was effected in 1976 and 1980-1983.

Tables 20 and 21 present results so far, under the headings of release methods and periods, and size of seed. The results show a number of differences by year, on such points as methods of calculation of survival rates, handling of seed at the time of release, and handling at the time of culture, and accurate comparison by the same standards cannot be made. However, the results show general tendencies.

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1. Natural falling release

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After beginning of release, no great natural decrease is observed until about July. However, decrease becomes rapid from summer to fall, and in October-November, the survival rate lowered to under 10%.

In release areas in summer, an increase in benthic organisms considered to prey on the young urchins was observed : these were a starfish (Asterina pectinifera) and crabs.

With intermediate release, there is a large natural decrease following the release, and the anticipated results do not appear. The reason for this is not quite clear but it seems that much of the released seed is eaten by the above starfish and by sand crabs (Hemigrapsus sanguineus).

2. Intermediate culture release

When seeds with a shell diameter of about 5 mm, cultured until mid-June were released, there was a great decrease after August, in the same manner as for natural release, and after half a year the survival rate was under 10%.

Table 20. Survival rates and growth of naturally released *S. intermedius* urchins

308-309

Period of release	Mean shell diam. (mm)	Survival & shell diameter after release		Actual no. of days (mo./date)		About 6 months	About 9 months	Place of release: date of quality at bottom	Nos. of individuals released	Estimated values
		Survival	Shell diam.	Survival rate %	Mean shell diam. (mm)					
April-May (Spring)	2.58 no	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Lakarajima 3-5m (0.3-0.5)	1977.5.10	about 60,000
May (Spring)	3.20 no	100	100	80th day (7/10)	11.6	100 (1.6)	100 (7.5)	Atsutoma 3-5m (0.3-0.5)	" "	about 30,000
	3.20 no	100	100	100 (7.5)				Lakarajima 3-5m (0.3-0.5)	1978.4.12	about 60,000
	3.20 nc	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Atsutoma 3-5m (0.3-0.5)	" "	about 60,000

Table 21. Survival rates and growth after release of *S. intermedius* seed, intermediate culture

Period of release	Mean shell diam. (mm)	Survival & shell diameter after release		Actual no. of days (mo./date)		About 6 months	About 9 months	Place of release: date of quality at bottom	Nos. of individuals released	Estimated values
		Survival	Shell diam.	Survival rate %	Mean shell diam. (mm)					
June (Spring)	4.9 nc	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Lakarajima 3-5m (0.3-0.5)	1977.5.10	about 60,000
July-Aug. (Summer)	6.6 yes	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Lakarajima 3-5m (0.3-0.5)	" "	about 30,000
	10.9 yes	100	100	80th day (7/10)	11.6	100 (1.6)	100 (7.5)	Atsutoma 3-5m (0.3-0.5)	1978.4.12	about 60,000
	16.3 yes	100	100	100 (7.5)				Lakarajima 3-5m (0.3-0.5)	" "	about 60,000
	17.0 no	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Atsutoma 3-5m (0.3-0.5)	" "	about 60,000
	9.3 yes	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Lakarajima 3-5m (0.3-0.5)	1977.5.10	about 60,000
	9.8 no	100	100	80th day (7/10)	11.6	100 (1.6)	100 (7.5)	Atsutoma 3-5m (0.3-0.5)	1978.4.12	about 60,000
	13.7 yes	100	100	100 (7.5)				Lakarajima 3-5m (0.3-0.5)	" "	about 60,000
	15.3 yes	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Atsutoma 3-5m (0.3-0.5)	" "	about 60,000
	15.7 yes	100	100	80th day (7/10)	11.6	100 (1.6)	100 (7.5)	Lakarajima 3-5m (0.3-0.5)	1977.5.10	about 60,000
	16.4 no	100	100	50th day (6/5)	15.5-17.0	100 (5.08)	100 (9.93)	Atsutoma 3-5m (0.3-0.5)	" "	about 60,000
	18.4 yes	100	100	80th day (7/10)	11.6	100 (1.6)	100 (7.5)	Lakarajima 3-5m (0.3-0.5)	1978.4.12	about 60,000
	18.7 yes	100	100	100 (7.5)				Lakarajima 3-5m (0.3-0.5)	" "	about 60,000

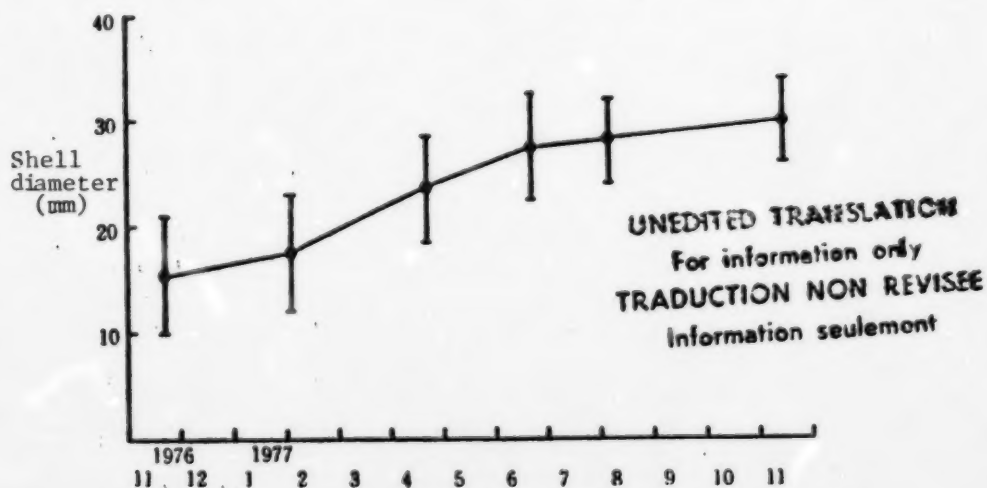
For those released in July-August, the mean shell diameter was in a scope 307 of 6.6-18.3 mm, and above 17 mm, the survival rate was high, but after half a year, the maximum survival rate was 35%, and results tended to be worse than for release in autumn.

For groups released in autumn, variations in survival rate were marked, 310 1 month after release, according to the group. However, in 3 examples of mean shell diameter 15-20 mm at the time of release, with the survival rate 60% 1 month after release, the rate 1 year later was comparatively high, at 24.3-74.6%, and moreover, decrease in the winter period was small. The survival rate up to a fishery catching size, 1 year after release, was not ascertained, but it may be thought that in natural fishing grounds, decrease is extremely low, and is virtually nonexistent.

The released seed grows well from winter to spring, and seeds with a shell diameter of 15-20 mm grew by an average of 10-15 mm (Fig. 19). It may be thought that in the Shakotan maritime area, 2-2.5 years after release are required in order to reach a diameter of 4 cm, the limit for fishing.

The first step in raising release effectiveness is not to lower the activity of the seed until release, and to minimize decrease immediately after release.

Fig. 19. Seasonal variations in growth of urchins released in November 1976



Among young urchins indicated by coloring, and lowered in activity, many had an extremely high decrease rate for about a month after release.

As for the period of release, June is unfavorable because seeds are small. On comparing release in July-August and October-November, the only difference is that the latter is somewhat safer, but for handling of seed in high summer temperatures, the disadvantages are that seed activity is lowered, and the activity of harmful organisms is high.

It appears that for release sizes, a shell diameter of over 15 mm, and in summer, a diameter of over 20 mm would be necessary.

There is no case of seed release with a shell diameter under 15 mm in low water temperatures after November, but the activity of foreign organisms also seems to lower in winter, so that it may be necessary to conduct release testing on small-size seeds. 311

As related above, in the 10-year survey, the technical basis for natural seed collection, intermediate culture and release of S. intermedius has been established. In order to put this technical system into practice and increase urchin resources, it is necessary to promote vigorously not only improvements in the usual methods, but also fisheries management, creation of fishing grounds, and general resource control and propagation policies.

SUMMARY

I. Life and environment of Strongylocentrotus intermedius from generation to benthic stage

1. Free-floating larvae are generated from September to October at water temperatures from 20°C to 15°C, and appear from about January. Moreover, amounts of appearance vary annually; those of metamorphosed larvae in 1979 were the greatest.

2. Free-floating larvae are distributed until about November 2,000-10,000 m offshore, while metamorphosed larvae tend to concentrate in shallow coastal waters from December to January. This shift in distribution corresponds well to seasonal change.
3. Most urchins decrease in the free-floating larval stage. However, it may be estimated that in the Shakotan maritime region, metamorphosed larvae appear in numbers ranging from several millions to several hundreds of millions per 1-Km of coastline.
4. S. intermedius benthic larvae were seen in great numbers in small-size vertical seaweed colonies on flat shoals and under rocks below 30 cm diameter. Numbers of young urchin appearing varied annually, the highest concentration of S. intermedius groups was in 1979. Nevertheless, natural distribution density was very low in contrast to density of those adhering to collectors.
5. S. intermedius groupings on flat shoals, age 0, decreased by over 40% in summer, from July to September.

II. Natural seed collection experiments

1. In collection facilities installed at 20-30 m water depth, almost no damage or washing away of facilities occurred.
2. Among the materials used for collectors, vinyl chloride, creosol, plastic washboard, and other rigid boards had greater adhesions than Hi-Zex film, Netron net, etc. Moreover, urchins adhered more readily to complex, uneven surfaces rather than flat ones, even of the same material.
3. In transparent materials, adhesion was great on interior surfaces, not only on exteriors, but in non-transparent materials, adhesion to interior surfaces was slight.
4. For collector boards, the 2-4 layer types had greater adhesion than single layers. However, in the case of 6 and 10 layers of vinyl chloride boards

of 30 x 45 cm or 45 x 45 cm size, numbers adhering were low.

5. For types of suspension of collectors, there was no great difference in numbers among the vertical, tubular or horizontal types. Dropoff was greatest from tubes and smallest from the horizontal type. Growth of adhering urchins was worst in the horizontal type. On 3-layer vinyl chloride boards, horizontal corrugations attracted greater numbers than vertical ones.

6. Numbers of young urchins adhering were great at a 20-30 m depth of installations, and numbers decreased the shallower the water, under 20 m. Even at the same 20 m depth, the order of numbers adhering, by location and year, changed.

7. If the number adhering to collectors in September installations was taken as 100, it was 34 for October and 3 for November.

8. The depths at which adhesions were numerous were 3-13 m at 20 m-deep installations, and 5-20 m at 30 m installations.

9. As for species of urchins adhering to collectors, almost all were S. intermedius, with very few S. nudus urchins.

10. The shell diameters of adhering S. intermedius urchins were under 1 mm in January, 1-3 mm in March, and 1-10 mm in May.

11. Annual variations were conspicuous in numbers adhering in January, and up to 1979 a tendency to be in proportion to appearance numbers of metamorphosed larvae was recognized. Adherence increased from January to March. Around April-May, individuals dropped off according to changes in time, and yearly variations in dropoff rate were significant. 313

12. Ascidiars adhered in great number to collectors other than vinyl chloride material, and numbers of urchins adhering were small, the greater the area covered.

13. Perhaps because few diatoms adhered to the collector boards, adhesion of urchins was slight on areas where diatoms were almost nonexistent.

III. Experiments on intermediate culture of urchin seed

1. For commencement of intermediate culture, the time before dropoff from collectors begins in the case of culture at sea, and when adhering kelp has developed somewhat, is favorable. In onshore culturing, water quality deteriorates if adhering materials are numerous, so that an earlier period is appropriate.
2. Knotweed is an effective feed, for shell diameters from 5-15 mm.
3. For amounts of feed administered, if control is good, the greater the amounts, the better the growth.
4. Under present techniques, the appropriate collection density is 2,000 individuals per culturing basket (in sea, 80 x 80 x 40 cm, onshore 90 x 70 x 40 cm).
5. For release, shell diameters reach 15 mm about 8-9 months after culturing begins, or from March to October-November.
6. Survival rates for seed during intermediate culturing vary according to conditions. In general, under good control, a rate of 70% can be expected. At high summer temperatures, care is required because survival rates decline sharply.

IV. Seed release surveys

1. Around April, when collectors were placed under the surface of urchin fishing grounds, and seeds released by natural falling, without intermediate culturing, there was a decrease of over 90% from summer to autumn.
2. There was a marked decrease after intermediate culture in seeds under 10 mm shell diameter, released in June-July, up to October.

3. The groups released in July-November, whose survival rate after 1 year was high, at 20-75%, were those with a shell diameter of 15-20 mm at the time of release, and whose decrease within 45 days after release was low.
4. The lowering of activity of seed during intermediate culture, through control, calculations, transport, and marking, etc., no doubt contributed greatly to decrease immediately after release.
5. Decrease in released seeds was often small during the winter period.
6. Seeds with a shell diameter of 15-20 mm grew by 10-15 mm in 1 year, and it may be estimated that they reached over 40 mm, the limit for fishing, 2-2.5 years after release.

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